(19) Japanese Patent Office (JP)

(12) Publication of Patent Applications (A)

(11) Publication number H10-164853

(43) Publication Date: June 19, Heisei 10 (1998)

(51) Int. Cl.[6]	ID Symbol	JPO Internal Ref. No.	FI		
H 02 M	7/48		H 02 M	7/48	M
	7/538				A
H 05 B	41/24			7/538	A
	41/29		H 05 B	41/24	L
				41/29	C

Request for examination: Not Requested
Number of claims: 14 OL (33 pages total)

(21) Filing Number: Tokugan H08-314352

(22) Filing Date: November 26, Heisei 8 (1996)

(71) Applicant: 000005832
Matsushita Electric Works, Ltd.
1048, Kadoma, Kadoma-shi, Osaka
(72) Inventor: **Hiroyuki Sako**
C/o: Matsushita Electric Works, Ltd.
1048, Kadoma, Kadoma-shi, Osaka
(72) Inventor: **Kazuhiro Nishimoto**
C/o: Matsushita Electric Works, Ltd.
1048, Kadoma, Kadoma-shi, Osaka
(72) Inventor: **Katsunobu Hamamoto**
C/o: Matsushita Electric Works, Ltd.
1048, Kadoma, Kadoma-shi, Osaka
(74) Agent **Keisei Nishikawa**, Patent Attorney
(Plus one other)

(54) [Title of the Invention]

ELECTRIC-POWER SUPPLY UNIT

(57) ABSTRACT

[Objective] [The objective of the present invention] is to suppress an increase in the power-supply voltage during light-load [states].

[Means of Resolution] [The present invention] is provided with a chopper circuit CH1 having an (electrical) capacitor C5 parallel-connected with an (electrical) capacitor C1 that serves as a pseudo power source between the pulsating-current output end of a rectifier DB, an inductance L2 and a switching element Q3. The switching element Q3 consists of a FET having a parasitic diode Da, and is turned on and off by a control circuit CNT1 that drives the main switching elements Q1 and Q2 of the inverter circuit INV1. By switching the switching element Q3 between ON and OFF [states] by the control circuit CNT1,
a circuit configuration can be selected in accordance with the operation modes of the inverter circuit INV1 (precedential preheating mode for pre-heating an electric-discharge lamp La in advance, and illumination mode for lighting up the electric-discharge lamp La). Therefore according to [the present invention], it becomes possible to concurrently achieve the prevention of an increase in the supply voltage to the inverter circuit INV1 during light-load [state] and the reduction of stress on the main switching elements Q1 and Q2.

[CLAIMS]

[Claim 1] An electric-power supply unit being provided with:

A rectifier for rectifying the alternating-current voltage source;

A first capacitor connected between the output ends of the rectifier;

An inverter circuit provided with a first and a second main switching elements that are series-connected to both ends of the first capacitor, as well as a resonant circuit that is parallel-connected to either one of the main switching elements; and

A control circuit for alternately switching the first and the second main switching elements between ON and OFF [states] at high frequency;

Said resonant circuit being formed having a first inductance for resonance, a second capacitor for resonance parallel-connected to a load, a third capacitor for coupling direct current, and a fourth capacitor parallel-connected with the first diode; and comprising:

Said parallel circuit of the fourth capacitor and the first diode being connected between the series circuits of the first capacitor and the first and the second main switching elements;

A sixth capacitor and a series circuit of the fifth capacitor and the second inductance as well as the second diode being parallel-connected to the series circuit of the first and the second main switching elements; and

The connection point of the first and the second main switching elements and the connection point of the second inductance and the second diode are connected to the third diode,

Wherein:

Said switching elements are provided in parallel to the second diode and are switched between ON and OFF by said control circuit according to the load state.

[Claim 2] An electric-power supply unit being provided with:

A rectifier for rectifying the alternating-current voltage source;

A first capacitor connected to the rectifier;

An inverter circuit provided with a first and a second main switching elements series-connected in parallel to the first capacitor as well as a resonant circuit parallel-connected to either one of the main switching elements; and

A control circuit for alternately switching the first and the second main switching elements between ON and OFF [states] at high frequency;

Said resonant circuit is configured having a first inductance for resonance, a second capacitor for resonance connected in parallel to a load, a third capacitor for coupling direct current, and a fourth capacitor to which the first diode is connected in parallel; and comprising

Said parallel circuit of the fourth capacitor and the first diode being connected between the first capacitor and the series circuits of the first and the second main switching elements,

A series circuit (of the second diode and the fifth capacitor as well as the second inductance) and a sixth capacitor being connected in parallel to the series circuit of the first and the second main switching elements, and

The connection point (of the first and the second main switching elements) and the connection point (of the second inductance and the second diode) being connected by the third diode;

Wherein said electric-power supply unit is further characterized by being provided with:

A pair of switching terminals provided at both ends of the second inductance,

A common terminal provided at the high-voltage side of the first main switching element, and

A switching circuit that, being controlled by said control circuit, alternatively switches and connects said common terminal to said pair of the switching terminals.

[Claim 3] The electric-power supply unit of Claim 1, characterized by being provided with a switching element that short-circuits between both ends of said fourth capacitor through the ON/OFF switching [operation] thereof carried out by said control circuit.

[Claim 4] The electric-power supply unit of Claim 1, characterized by comprising a series circuit of said switching elements (that is switched between ON and OFF by said control circuit) and the 7th capacitor being parallel-connected to the fourth capacitor.

[Claim 5] The electric-power supply unit of Claim 2, characterized by:

Being provided with a switching element that short-circuits between both ends of said fourth capacitor through the ON/OFF switching [operation] thereof carried out by said control circuit; and

Comprising a series circuit of said switching elements (that is switched between ON and OFF by said control circuit) and the 7th capacitor being parallel-connected to the fourth capacitor.

[Claim 6] An electric-power supply unit provided with:

A rectifier for rectifying the alternating-current voltage source;

An inverter circuit that converts the output of said rectifier into a high frequency output and supplies it to a load, said inverter circuit being provided with one or multiple main switching elements switched at high frequency as well as having a resonant circuit comprising one or multiple inductances for resonance, a capacitor for resonance, a capacitor (which is adapted for cutting the direct-current component) and a load; and

A power-supply circuit that is provided with one or multiple capacitors for partial smoothing and performs partial smoothing of the output of said rectifier;

Wherein:

Said electric-power supply unit is [further] characterized by being provided

with:

A feedback means for returning a portion of the high frequency output of said inverter circuit to the output side of the rectifier via said resonant circuit, and

A control means for causing the oscillation of said inverter circuit to start when the absolute value of the alternating-current supply voltage is lower than that of the end-to-end voltage of the capacitor (which is adapted for partial smoothing)

[Claim 7] The electric-power supply unit of Claim 6, characterized by being provided with a means for charging the capacitor (which is adapted for partial smoothing) before the oscillation of said inverter circuit starts

[Claim 8] The electric-power supply unit of Claim 7, characterized by being provided with a means for charging the capacitor (which is adapted for cutting the direct-current component and comprises said resonant circuit) until the end-to-end voltage of the capacitor (which is adapted for cutting the direct-current component) reaches a state lower than the end-to-end voltage of the capacitor (which is adapted for partial smoothing), before the oscillation of said inverter circuit starts.

[Claim 9] An electric-power supply unit according to either on of the claims 6 through 8, characterized by being provided with a detection means for detecting the zero-cross of the alternating-current supply voltage, wherein said control means is configured to cause the oscillation of said inverter circuit to start when the detection means detects the zero-cross.

[Claim 10] An electric-power supply unit provided with:

A rectifier for rectifying the alternating-current voltage source,

An inverter circuit that is provided with one or multiple main switching elements switched at high frequency and that converts the direct-current output into a high-frequency AC output and supplies it to a load, and

A partial smoothing circuit that has one or multiple capacitors as well as inductances, and that supplies, to said inverter circuit, said direct-current output, which was [obtained] by charging said capacitor through the ON-OFF operation of said main switching elements and partially smoothing

the pulsating current output of the rectifier;

Wherein:

The capacitor of said partial smoothing circuit being series-connected to said main switching elements via the inductance; and

The charge circuit (for charging said capacitor before the operation of said inverter circuit starts up) being parallel-connected to the series circuit of said inductance and the main switching elements.

[Claim 11] The electric-power supply unit of Claim 10, characterized by being configured in such a way that the electric charging [operation of said capacitor] by said charge circuit is discontinued once said capacitor is charged up to or greater than a prescribed level.

[Claim 12] The electric-power supply unit of Claim 11, characterized by said charge circuit being equipped with an opening-and-closing means that opens and closes the electric charging route of said capacitor.

[Claim 13] The electric-power supply unit of Claim 12, characterized by said opening-and-closing means starting its operation before the main switching elements of the inverter circuit [do], and the ON-OFF operation [of the opening-and-closing means] being repeated in synchronization with the ON-OFF operation of said main switching elements.

[Claim 14] The electric-power supply unit of Claim 12, wherein said opening-and-closing means is characterized by the ON-OFF operation [thereof] being repeated in accordance with the charge-voltage level of said capacitor.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an electric-power supply unit provided with an inverter circuit.

[0002]

[Conventional Technology]

Conventional electric-power supply units include those provided with an inverter circuit that converts a direct-current output (which is obtained by rectifying and smoothing the alternating-current voltage source) into a high frequency alternating-current output. Some of such conventional devices are described below.

(Conventional Example 1)

Figure 35 is a circuit diagram of the present conventional examples described in JP,8-149845,A. The present conventional example an alternating-current voltage source AC; a choke coil L0 for cutting high-frequency current, a rectifier DB configured by bridge-connecting diodes D1-D4; a capacitor C1 that serves as a pseudo power source as being connected between the output ends of the rectifier DB; an inverter circuit INV1 connected to this capacitor C1 in parallel; a control circuit CNT0 wherein the inverter circuit INV1 causes a series-connected pair of the main switching elements Q1 and Q2 provided therein to alternately switch between ON and OFF; and a chopper circuit CH1 that is provided with an electrolytic capacitor C5, an inductance L2, diodes D0, D7 and a capacitor C6 and shares one of the main switching element Q2 of the inverter circuit INV1. It is to be noted that, other than a field-effect transistor (FET), a bipolar transistor that connects a diode in anti-parallel may be used for each [pair of the] main switching elements Q1 and Q2.

[0003] In the inverter circuit INV1, a series circuit of a pair of the main switching elements Q1 and Q2 is parallel-connected to the capacitor C1. In the main switching element Q2 at the low-voltage side, a resonant circuit RE1 (which consists of a capacitor C3 for cutting (coupling) the direct-current component, a choke coil (inductance) L1 for resonance, an electric-discharge lamp La, a capacitor C2 for resonance, a capacitor C4 for improving the input current distortion, and a diode D6 parallel-connected to the capacitor C4) is connected in parallel. (Refer to JP,5-38161,A, Japanese Patent Application [Tokugan] H07-310269, etc. for the structure and the operation of this inverter circuit INV1.)

[0004] The following is an explanation of the circuit operation of the present

conventional example. The main switching elements Q1 and Q2 of the inverter circuit INV1 are alternately switched between ON and OFF at high frequency by the control circuit CNT0. Therefore, when the main switching element Q1 at the high-voltage side is ON, the resonance current flows from the capacitor C1 via the route of the main switching element Q1 → capacitor C3 → inductance L1 → electric-discharge lamp La and capacitor C2 → diode D5 → capacitor C1, in case of (output voltage Vdc of chopper circuit CH1) < (end-to-end voltage Vc4 of end-to-end voltage Vc1 + capacitor C4 of capacitor C1); while in case of Vdc > Vc1+Vc4, the resonance current flows from the chopper circuit CH1 via the route of the main switching element Q1 → capacitor C3 → inductance L1 → electric-discharge lamp La and capacitor C2 → capacitor C4 → chopper circuit CH1. And when the main switching element Q2 at the low-voltage side is ON, the electric charge of the capacitor C3 is discharged and the resonance current flows via the route of the capacitor C3 → main switching element Q2 → diode D6, capacitor C4 → electric-discharge lamp La and capacitor C2 → inductance L1 → capacitor C3.

[0005] Herein, the energy accumulated in the inductance L1 while the main switching element Q1 is ON is discharged through the capacitor C3 and the diode D7 when the main switching element Q1 is turned OFF and charges the capacitor C5 of the chopper circuit CH1. And the energy accumulated in the inductance L2 of the chopper circuit CH1 while the main switching element Q2 is ON is discharged through the diode D7 and a parasitic diode (not shown) of the main switching element Q1 when the main switching element Q2 is turned OFF and charges the capacitor C5.

[0006] Because the present conventional example can channel the input current (the resonance current) over the entire zone of the alternating-current voltage source AC, it can improve the distortion of the input current. Additionally, because it can embed the valley part of the end-to-end voltage Vc1 of the capacitor C1 serving as a pseudo power source with output voltage Vc5 of the chopper circuit CH1 as shown in Figure 36, it can improve the distortion of the input current without causing an idle period of the supply voltage Vdc of the inverter circuit INV1; while it can also improve the load current waveform given that it can also reduce the peak value of the supply current to an electric-discharge lamp La (which is the load). Further, providing a chopper circuit CH1 when using an electric-discharge lamp La as the load can increase the charging voltage of the capacitor C4 of the inverter circuit INV1 during light-load [states] (during a precedential preheating, during no-load states, or while lighting up a dimmed light) or during abnormal-load conditions, such as at the end stage of the lamp's service life, and thereby enabling an escape from the problem of the step-up of the

supply voltage Vdc of inverter circuit INV1.

[0007] (Conventional Example 2)
The second conventional example includes [an electric-power supply unit] described in JP,59-220081,A. The schematic circuit diagram is shown in Figure 37; the operation waveform chart is shown in Figure 38. The present conventional example is an electric-power supply unit that converts a direct-current output (which is obtained by rectifying an alternating-current voltage source AC with a rectifier DB via a filter circuit F) into an alternating-current power by an inverter circuit INV6', and supplies it to an electric-discharge lamp La (which is the load).
[0008] Here, the filter circuit F comprises an inductance L0 connected to one end of the alternating-current voltage source AC, and a capacitor C1 parallel-connected to both ends of the alternating-current voltage source AC via the inductance L0. The inverter circuit INV6' is a so-called half-bridge inverter circuit that achieves the high-frequency illumination of the electric-discharge lamp La (which is the load) by the main switching elements Q1 and Q2 repeatedly switching between the ON and OFF states alternately; and comprises a series circuit of a pair of the main switching elements Q1 and Q2; a capacitor C6 parallel-connected to both ends of the series circuit of the main switching elements Q1 and Q2; a series circuit of a capacitor C5 for partial smoothing (infilling of the valley [section]), an inductance L2 and a diode D0 parallel-connected to both ends of the series circuit of the main switching elements Q1 and Q2; a diode D7 connected between the connection point of the main switching elements Q1 and Q2, and the connection point of the diode D0 ~ the inductance L2; and a series circuit of the capacitor C3 (for cutting the direct-current components), and a load circuit 3 connected between the connection point of the main switching elements Q1 and Q2, and the positive output terminal of the rectifier DB. It is to be noted that the main switching elements Q1 and Q2 alternately switch between ON and OFF under the control of the control circuit CNT6'. Also comprised [therein] is a (valley-infill) power supply circuit 1' that supplies power from the main switching elements Q1 and Q2, inductance L2, capacitor C5 for partial smoothing, and diodes D7, D0 to the inverter circuit INV6'. The load circuit 3 comprises a series connection of an inductance L1 and a primary winding n1 of a transformer T 1 connected between the positive output terminals of the capacitor C5 and the rectifier DB;
a capacitor C2 for resonance parallel-connected to both ends of the primary winding n1 of the transformer T 1; and an electric-discharge lamp La connected in parallel to both ends of a secondary winding n2 of the transformer T. Further, the series circuit consists of the capacitor C3 (for cutting the direct-current

components), the inductance L1, the primary winding n1 of the transformer T1 and the capacitor C2 comprises a high-frequency-output feedback means for returning a portion of high frequency outputs of the inverter circuit INV6' to the output end of the rectifier DB.

[0009] The following is a brief explanation of the operation. First, the operation at the near-peak (VAC>=Vc6) of the alternating-current voltage source AC is briefly explained as follows:

When the main switching element Q1 turns on and the switching element Q2 turns off, the input current Iin flows via the route of the alternating-current voltage source AC→ filter circuit F→ rectifier DB→ Lord switching element Q1 → diode D7 → inductance L2 → capacitor C5 → rectifier DB→ filter circuit F→ alternating-current voltage source AC; while the resonance current flows via the route of the inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → main switching element Q1 → capacitor C3 → inductance L1. When the main switching element Q1 turns off and Q2 turns on, regenerative current of the inductance L2 flows via the route of the inductance L2 → capacitor C5 → main switching element Q2 → diode D7 → inductance L2; while the resonance current (namely, regenerative current of the inductance L1) flows via the route of the inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → capacitor C6 → main switching element Q2 → capacitor C3 → inductance L1. In time, the direction of the resonance current flowing through the inductance L1 is reversed, and [thereafter the resonance current] flows via the route of the capacitor C6 → capacitor C2, the primary winding n1 of the transformer T1 → inductance L1 → capacitor C3 → main switching element Q2 → capacitor C6. And when the main switching element Q1 turns on and Q2 turns off, the input current flows via the route of the alternating-current voltage source AC→ filter circuit F→ rectifier DB→ main switching element Q1 → diode D7 → inductance L2 → capacitor C5 → rectifier DB→ filter circuit F→ alternating-current voltage source AC; while the resonance current (namely, regenerative current of the inductance L1) flows via the route of the inductance L1 → capacitor C3 → main switching element Q1 → capacitor C2, the primary winding n1 of the transformer T1 → inductance L1.

[0010] Because the capacitor C6 is charged from the alternating-current voltage source AC in this case, the waveform of the end-to-end voltage Vc6 of the capacitor C6 shows an approximately similar figure relative to the change of the alternating-current voltage source AC, as shown in Figure 38 (a). Additionally, the input current Iin having a waveform with an approximately similar figure relative to the change of the alternating-current voltage source AC, as shown in Figure 38

(b), flows only when the main switching element Q1 is ON as described above. When the current thereof is filtered by a filter circuit F, the input current Iin with a wide conduction angle as shown in Figure 38 (b) may be obtained and thus it is possible to [thereby] improve the input-power factor. The lamp current ILa, as shown in Figure 38 (b), shows a high-frequency-current waveform of an alternating current, having an envelope curve with an approximately similar figure relative to the change of the end-to-end voltage Vc6 of the capacitor C6.

[0011] Next, the operation at the near-valley (VAC<=Vc6) of the alternating-current voltage source AC is briefly explained in the following. When the main switching element Q1 turns on and Q2 turns off, the valley-infill current flows via the route of the capacitor C5 → inductance L2 → diode D0 → capacitor C6 → capacitor C5; while the resonance current flows via the route of the inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → main switching element Q1 → capacitor C3 → inductance L1. When the main switching element Q1 turns off and Q2 turns on, the valley-infill current flows via the route of the capacitor C5 → inductance L2 → diode D0 → capacitor C6 → capacitor C5; while the resonance current (namely, regenerative current of the inductance L1) flows via the route of the inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → capacitor C6 → switching element Q2 → capacitor C3 1 inductance L1. In time, the direction of the resonance current flowing through the inductance L1 is reversed, and [thereafter the resonance current] flows via the route of the capacitor C6 → capacitor C2, the primary winding n1 of the transformer T1 → inductance L1 → capacitor C3 → main switching element Q2 → capacitor C6. And when the main switching element Q1 turns on and Q2 turns off, valley-infill current flows via the route of the capacitor C5 → inductance L2 → diode D0 → capacitor C6 → capacitor C5;

while the resonance current (namely, regenerative current of the inductance L1) flows via the route of the inductance L1 → capacitor C3 → main switching element Q1 → capacitor C2, the primary winding n1 of the transformer T1 → inductance L1.

[0012] In this case, the capacitor C6 gradually discharges the electric charge to the capacitor C5 and the load circuit 3. Accordingly, the waveform of the end-to-end voltage Vc6 of the capacitor C6 gradually drops as shown in Figure 38 (a), and the input current Iin does not flow as shown in Figure 38 (b). The lamp current ILa, as shown in Figure 38 (b), shows a high-frequency-current waveform of an alternating current, having an envelope curve with an approximately similar figure relative to the change of the end-to-end voltage Vc6 of the capacitor C6.

[0013] Meanwhile, as described above, the partial smoothing capacitor C5 is

charged only when the main switching element Q1 turns on, while the inductance L2 is interposed in the electric charging route of the capacitor C5. Given these factors, therefore, the value of the end-to-end voltage Vc5 of the capacitor C5 becomes lower than the peak voltage [obtained through] rectifying the alternating-current voltage source AC, as shown in Figure 38 (a). Thus, the waveform of the end-to-end voltage Vc6 of the capacitor C6 shows a voltage waveform comprising a ripple, as shown in Figure 38 (a); [whereas] the waveform of the lamp current ILa shows a current waveform comprising a ripple that follows after the change of the end-to-end voltage Vc6 of the capacitor C6 as shown in Figure 38 (c).

[0014] (Conventional Example 3)
The third conventional example includes the elements described in JP,8-149845,A. The schematic circuit diagram is shown in Figure 39; and the operation waveform chart is shown in Figure 40. The difference from Conventional Example 2 shown in Figure 37 is having the parallel circuit of the capacitor C4 and the diode D6 interposed between the high-voltage sides of the main switching element Q1 and the positive output terminal of the rectifier DB.
The explanation of the other configurations identical to Conventional Example 2 shall be omitted herein by affixing the identical reference coding therewith. [0015] According to the present conventional example, because, across the almost entire interval of one cycle of the alternating-current voltage source AC, the current is supplied from the alternating-current voltage source AC to the inverter circuit INV6' according to the ON and OFF of the main switching elements Q1 and Q2, it becomes possible to form the waveform of the input current Iin into an approximate sine-wave shape as shown in Figure 40 (b); therefore, it becomes possible to improve the input-power factor and the input current waveform distortion, making it also possible to substantially reduce harmonic content.
[0016] Meanwhile, in the case of the present conventional example, the resonance system of the inverter circuit INV6' is altered depending on the size of the alternating-current voltage source AC. The resonance system at the near-peak of the alternating-current voltage source AC consists of [<sic> becomes] the inductance L1, the capacitor C2, the primary winding n1 of the transformer T1, and the electric-discharge lamp La; whereas, the resonance system at the near-valley of the alternating-current voltage source AC consists of [<sic> becomes] the inductance L1, the capacitor C2, the primary winding n1 of the transformer T1, the electric-discharge lamp La, and the capacitor C4. Accordingly, the lamp current ILa as shown in Figure 40 (c) comes to approach the maximum

values respectively near the zero-cross and near the peak of the power-supply voltage VAC of the alternating-current voltage source AC. In other words, by combining the resonant circuit in inverse proportion to the size of the alternating-current voltage source voltage VAC and the end-to-end voltage Vc6 of the capacitor C6, the low frequency ripple of the output is substantially reduced. Accordingly, the crest factor CF (= a peak value/actual value) of the lamp current ILa is also improved, and along with it, the lamp power-factor is improved, [thereby] improving the luminous efficiency of the lamp as well.

[0017] It is to be noted that, also in either of the above-mentioned conventional examples 2 and 3, because the charging current of the capacitor C5 for partial smoothing does not flow unless either of the main switching elements Q1 and Q2 turns on, it becomes possible to suppress inrush current when the power is turned on. However, the following problems arise in the above-mentioned conventional examples 2 and 3. During the period from the time at which the power is turned on until the time at which the oscillation of the inverter circuit INV6' starts, the circuit shown in Figure 39 is equivalent to the circuit as shown in Figure 41. A capacitor C5 for partial smoothing and a capacitor C3 (for cutting the direct-current components) are provided [<sic> exist] in this equivalent circuit, as the direct-current impedance constituents on the route of alternating-current voltage source AC→ filter circuit F→ rectifier DB→ capacitor C2, the primary winding n1 of the transformer T1 → inductance L1 → capacitor C3 → diode D7 → inductance L2 → capacitor C5 → rectifier DB→ filter circuit F→ alternating-current voltage source AC. However, because the capacity of the capacitor C5 is extremely large in comparison with the capacity of the capacitor C3, most of the alternating-current voltage source AC via the filter circuit F and the rectifier DB is impressed on the capacitor C3. On the other hand, in the steady state during which the main switching elements Q1 and Q2 oscillate by 50% of the duty ratio, voltage that is approximately half of the end-to-end voltage Vc6 of the capacitor C6 is impressed on the capacitor C3 at all times.

[0018] In other words, there is a large difference in the end-to-end voltage Vc3 of the capacitor C3 between the period from the time at which the power is turned on until the time at which the oscillation of the inverter circuit INV6' starts, and the period from the time at which the inverter circuit INV6' started the oscillation until the time at which it returns to a steady state. Accordingly, the excessive electric charge charged by the capacitor C3 while the main switching element Q1 is ON is discharged once the oscillation of the inverter circuit INV6' starts, resulting in the flow of a large current I1, as shown in Figure 43 (b), via the route of the capacitor C3 → inductance L1 → capacitor C2, the primary winding n1 of the

transformer T1 → main switching element Q1 → capacitor C3, as shown in Figure 42; further resulting in a large stress to be applied to the main switching element Q1. In order to avoid this, high current-capacity semiconductor elements are required, generating increases in the size of a device, the cost, etc.

[0019] (Conventional Example 4)

The schematic circuit diagram of the fourth conventional example, which resolved the above-mentioned problems, is shown in Figure 44. (This circuit configuration has been proposed by the applicant of the present invention in the Japanese Patent Application [Tokugan] No. H07-310268.) The point in which the present conventional example differs from Conventional Example 3 shown in Figure 39 is that: a diode D10 is connected in anti-parallel to both ends of the series circuit of the inductance L2 and the capacitor C5 for partial smoothing; a diode D11 is connected between the anode of the diode D7, and the connection point of the main switching element Q2 and the capacitor C3 (for cutting the direct-current components); and a diode D19 is connected in anti-parallel to both ends of the series connection of the main switching element Q1 and the diode D11. The explanation of the other configurations identical to Conventional Example 3 shall be omitted herein by affixing the identical reference coding therewith. It is to be noted that the present circuit uses MOSFET for the main switching elements Q1 and Q2.

[0020] Next, the operation is briefly explained in the following. When the main switching element Q1 turns off and Q2 turns on, the resonance current flows via the route of the capacitor C6 → capacitor C4 → capacitor C2, the primary winding n1 of the transformer T1 → inductance L1 → capacitor C3 → main switching element Q2 → capacitor C6, when the end-to-end voltage Vc6 of the capacitor C6 is larger than the total of the output voltage of the rectifier DB and the end-to-end voltage of the capacitor C4; while, when the end-to-end voltage Vc6 of the capacitor C6 is smaller than the total of the output voltage of the rectifier DB and the end-to-end voltage of the capacitor C4, the resonance current (= the input current) flows via the route of the alternating-current voltage source AC→ filter circuit F→ rectifier DB→ capacitor C2, the primary winding n1 of the transformer T1 → inductance L1 → capacitor C ·· the 3 → main switching element Q2 → rectifier DB→ filter circuit F→ alternating-current voltage source AC; and [thereby] energy is accumulated in the inductance L1. And when the main switching elements Q1 and Q2 turn off,

via the route of the inductance L1 → capacitor C3 → diode D19 → capacitor C6 → rectifier DB→ filter circuit F→ alternating-current voltage source AC → capacitor

C2, the primary winding n1 of the transformer T1 → inductance L1, the energy accumulated in the inductance L1 is discharged, and the input current flows. Subsequently, when the main switching element Q1 turns on and Q2 turns off, the resonance current flows via the route of the capacitor C3 → inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → Capacitor C4 → main switching element Q1 → diode D11 → capacitor C3; and the charging electric-charge of the capacitor C4 is discharged; also energy is accumulated in inductance L1; whereas, when the charging electric-charge of the capacitor C4 is gone, the resonance current flows via the route of the capacitor C3 → inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → diode D6 → main switching element Q1 → diode D11 → capacitor C3. Additionally, only at the near-peak of the alternating-current voltage source AC (namely, when end-to-end voltage Vc6 of the capacitor C6 is smaller than the total of the output voltage of the rectifier DB and the end-to-end voltage of the capacitor C4), the input current flows via the route of the alternating-current voltage source AC→ filter circuit F→ rectifier DB→ capacitor C4, diode D6 → main switching element Q1 → diode D7 → inductance L2 → capacitor C5 → rectifier DB→ filter circuit F→ alternating-current voltage source AC. And when the main switching elements Q1 and Q2 turn off, via the route of the Inductance L1 → capacitor C2, the primary winding n1 of the transformer T1 → capacitor C4, diode D6 → capacitor C6 → parasitic diode of the switching element Q2 (not shown) → capacitor C3 → inductance L1, the energy accumulated in the inductance L1 is discharged, and the resonance current flows.

[0021] In other words, during the period from the time at which the power is turned on until the time at which the oscillation of the inverter circuit INV6' starts, because the main switching elements Q1, Q2 and the diode D11 are turned off, the capacitor C3 for cutting the direct current is not charged with an electric charge, nor does the overcurrent due to the capacitor C3 occur immediately after the start of the oscillation of the inverter circuit INV6' starts.

(Conventional Example 5)

The schematic circuit diagram of the fifth conventional example is shown in Figure 45, and the operation waveform chart thereof is shown in Figure 46.

It is to be noted that this circuit configuration has been proposed by the applicant of the present invention in Japanese Patent Application [Tokugan] No. H07-254210. [0022] According to the present conventional example, an inverter circuit INV9 is configured so as to be parallel-connected to a capacitor C3, a series circuit of the main switching elements Q1 and Q2, and a series circuit of an

inductance L2, capacitor C5 and diode D7, between the output ends of a rectifier DB for rectifying and smoothing the alternating-current voltage source AC; as well as being provided with a diode D0 connected between the connection point of the main switching elements Q1 and Q2, and the connection point of the capacitor C5 and the diode D7; and further comprising a series circuit of the resistor R14 and a switching element Q8 connected in parallel to the main switching element Q2. Also, a load Z is parallel-connected to the main switching element Q2 via the inductance L3 and the capacitor C16. The main switching elements Q1 and Q2 are alternately switched between ON and OFF by an oscillation circuit 7, and the switching element Q8 is switched between ON and OFF by a starting circuit 8. It is to be noted that the starting circuit 8 also controls the oscillation circuit 7.

[0023] Next, the circuit operation is explained as follows:

First, the operation of the inverter circuit INV9 is stopped until a certain period of time lapses from the time at which the power is turned on, by turning on the switching element Q8 through operation of the starting circuit 8 and by turning off the main switching elements Q1 and Q2 through control of the oscillation circuit 7. During such a halt period of the inverter circuit INV9, an electric current flows via the route of the rectifier DB → inductance L2 → capacitor C5 → diode D7 → main switching element Q2, and thereby the capacitor C5 is charged. And once the above-mentioned certain period of time has lapsed, the starting circuit 8 then turns off the switching element Q8 while controlling the oscillation circuit 7 to alternately switch the main switching elements Q1 and Q2 between ON and OFF. Thereafter, by repeating the switching of the main switching elements Q1 and Q2 between ON and OFF by the oscillation circuit 7, high-frequency power { which is determined by drive frequencies (oscillating frequency of the oscillation circuit 7) of the inductance L1, the capacitor C6, the impedance of the load Z and the main switching elements Q1 and Q2} is supplied to the load Z.

[0024] And in the (valley-infill) power supply circuit comprising an inductance L2, a capacitor C5 and diodes D7 and D0, the (valley-infill) capacitor C5 for partial smoothing is charged by channeling the electric current via the route of the alternating-current voltage source AC→ rectifier DB→ inductance L2 → capacitor C5 → diode D7 → main switching element Q2 → rectifier DB→ alternating-current voltage source AC when the main switching element Q2 is ON. Herein, as shown in Figure 46 (a), when the input voltage Vi from the rectifier DB becomes lower than the end-to-end voltage Vc5 of the capacitor C5, the capacitor C5 will no longer be charged, and thus having the charging electric-charge of the capacitor C5 being discharged via the diode D0, the discharge current as shown in Figure 46 (c) flows. At this time, the input voltage waveform of the inverter circuit INV9 will become

as shown in Figure 46 (b). In other words, when the input voltage Vi from the rectifier DB is higher than the end-to-end voltage Vc5 of the capacitor C5 as shown in Figure 46 (d), it charges the capacitor C5 operating as a voltage step-down chopper circuit; whereas, when the input voltage Vi is lower than the end-to-end voltage Vc5, it carries out the valley-infill (partial-smoothing) operation through which the electric charge of the capacitor C5 is discharged as mentioned above.

[0025] Now, let's consider the case in which there is no series circuit of the resistor R14 and the switching element Q8 [provided thereto]. During the halt state of the inverter circuit INV9 immediately after the power is turned on, the capacitor C5 will not be charged; but the charging current will begin to flow into the capacitor C5 via the above-mentioned route when the main switching element Q2 turns on. The energy accumulated in the inductance L2 with this charging current is discharged when the main switching element Q2 is OFF, via the route of the inductance L2 → capacitor C5 → diode D7→ parasitic diode of the main switching element Q1 → inductance L2. Additionally, the peak value of the charging current of the capacitor C5 is expressed with the ON-time t of the main switching element Q2 using the following formula:

[0026] (Vi - Vc5) x t / L2

As can be understood from the formula above, the lower the charge voltage of the capacitor C5 is, the higher the value of the electric-current that flows into the main switching element Q2. Furthermore, because the time required for the energy release of the inductance L2 also becomes longer, in the event that the main switching element Q2 turns on the next time, the inductance L2 will not be able to discharge all of the energy, and [thus] the current will end up flowing into the parasitic diode of the main switching element Q1.

[0027] For this reason, as shown with point A in Figure 47 (c) and (d), the momentary short circuit current will occur in the main switching elements Q1 and Q2 during the reverse recovery time of the parasitic diode of the main switching element Q1. Additionally, until the end-to-end voltage Vc5 of the capacitor C5 reaches the prescribed value, the main switching element Q2 will turn on while the energy of the inductance L2 cannot be discharged; and the electric current that flows into the inductance L2 and the capacitor C5 will become direct current that will become greater in time as shown in Figure 47 (b).

As a result, the stress will continue to be impressed on the main switching elements Q1 and Q2. Given this factor, the above-mentioned present conventional example prevents an excessive stress from being impressed on the main switching elements Q1 and Q2 by charging the capacitor C5 during the halt period of the inverter circuit INV9 immediately after turning on the power.

[0028]

[Objectives to Be Resolved by the Invention]

In the above-mentioned conventional example 1, the supply voltage Vdc of the inverter circuit INV1 forms [<sic> becomes] a voltage whose valley-section is infilled (i.e., which is smoothed in part) as shown in Figure 48. Given this factor, when an optimal design is incorporated [<sic> performed] such as to be able to obtain high efficiency with the operating frequency of the normal illumination mode in the event that a discharge lamp La is used as the load. [This] will cause no problem at the higher section (peak area) of the power-supply voltage Vdc, since the electric-current waveform (drain current waveform) of the main switching elements Q1 and Q2 in the inverter circuit INV1 forms an electric-current waveform somewhat showing phase-delay [<sic> phase-delay-like waveforms] at said higher section (peak area) of the power-supply voltage Vdc, as shown in Figure 49. (See said figure (b)). However, there will be a problem at the valley section (where the power-supply voltage Vdc is low), because, due to the drop of the power-supply voltage Vdc, the waveform will change [<sic> become] from said phase to a condition somewhat indicating phase-advance [<sic> waveform form close to phase-advance] (See said figure (c)), resulting in an increase of stress upon the main switching elements Q1 and Q2, which will then result in generation of heat and corruption. On the other hand, when attempting to make the electric-current waveforms of the main switching elements Q1 and Q2 into the waveforms with a phase-delay at the valley section of the power-supply voltage Vdc, it will result in the formation of a waveform with a furthermore phase delay at the peak of the power-supply voltage Vdc. This will then cause problems such as deviation from the ASO (area of safety operation) of the field-effect transistor comprising the main switching elements Q1 and Q2, or increased generation of heat due to on-resistance, or an excessive amount of wattless current in the resonant circuit resulting in an inefficient inverter circuit. [Accordingly, this approach has the disadvantage that designing the inverter circuit is difficult (the first problem).]

[0029] Moreover, according to Conventional Example 4 as mentioned above, although there will be no overcurrent immediately after the oscillation of the inverter circuit INV6' starts because the capacitor C3 (for cutting the direct-current components) is not charged with the electric charge, it is associated with other problems as listed below. That is: When the charge voltage of the capacitor C3 immediately after the oscillation of the inverter circuit INV6' is equal to zero on one hand while the main switching elements Q1 and Q2 oscillate by 50%

of the duty ratio under the steady normal operating state of the inverter circuit INV6', the charge voltage of the capacitor C3 becomes approximately half of the voltage Vc2 at both ends the capacitor C2, resulting in a large difference in the end-to-end voltage Vc3 of the capacitor C3. As shown in Figure 50, once the oscillation of the inverter circuit INV6' starts, the electric current I2 as shown in said figure (b) flows from the power supply circuit 3 via the route of the primary winding of the transformer T 1 → inductor L2 → capacitor C3 → main switching element Q1. At this time, because the charge voltage (end-to-end voltage) Vc3 of the capacitor C3 for cutting the direct current is equal to zero, the direct current flows for charging the capacitor C3 to the steady-state voltage. Thus, the electric-current waveforms of the main switching elements Q1 and Q2 comprise the waveforms as shown in Figure 50 (c) and (d); and the electric current of the main switching element Q1 will switch [when it is] under zero for several cycles immediately after the oscillation of the inverter circuit INV6' starts. At this time, a momentary short-circuit current as shown in point A of said figure (c) and (d) will be generated during the reverse recovery time of the parasitic diode of the main switching element Q1.

[0030] Excessive stress (which is generated due to said momentary short-circuit current) may be prevented from being impressed on the main switching elements Q1 and Q2, simply by speeding up [<sic> sharpening] the resonance immediately after the oscillation of the inverter circuit INV6' starts. In other words, speeding up [<sic> sharpening] the resonance immediately after the oscillation of the inverter circuit INV6' starts will increase the amplitude of the above-mentioned electric current I2, and enable the main switching elements Q1 and Q2 to operate with timing at which [<sic> of] the electric current I2 is positive or negative; and thereby it can prevent the occurrence of the above-mentioned short circuit current. However, during a prescribed period immediately after the oscillation of the inverter circuit INV6' starts in case of using an electric-discharge lamp as the load, the initiation of the electric-discharge lamp is typically performed after supplying preheating current to the filament of the electric-discharge lamp by slowing [<sic> dulling] the resonance and completing sufficient preheating. Accordingly, if the resonance is slowed down [<sic> dulled] immediately after the oscillation of the inverter circuit INV6' starts, the filament of the electric-discharge lamp cannot be preheated in advance, causing a sudden impression of high voltage, which will then cause instantaneous illumination of the electric-discharge lamp. Such a sudden initiation of an electric-discharge lamp without a precedential preheating will cause problems such as a shorter service life of the electric-discharge lamp (the second problem).

[0031] Furthermore, the above-mentioned conventional example 5 is associated with problems as listed below. When the end-to-end voltage Vc5 of the capacitor C5 is low relative to the input voltage Vi, the voltage waveform of the diode D0 during the charging period of the capacitor C5 will be the waveform as shown in Figure 46 (e). The maximum value of the voltage impressed on the diode D0 becomes approximately equal to the maximum voltage value Vimax of the above-mentioned valley-infill power source (partial-smoothing power source). Furthermore, the maximum value of the voltage impressed on the main switching element Q2 also becomes equal to the above-mentioned maximum voltage value Vimax. Accordingly, given that the switching element Q8 is OFF while the inverter circuit INV9 is in operation, the maximum voltage value Vimax of the above-mentioned valley-infill power source (partial smoothing power source) will be impressed [on the switching element Q8], requiring it to be a switching element with the same level of withstanding voltage as that of the main switching elements Q1 and Q2 of the inverter circuit INV9, which will then require an increase in the size of the switching element Q8 (the third problem).

[0032] The purpose of the inventions of the claims 1 through 5 is to resolve the above-mentioned first problem; and thus it aim to provide an electric-power supply unit that can suppress increase of power-supply voltage during light-load [states]. Additionally, the inventions of the claims 6 through 9 propose to resolve the above-mentioned second problem, and thus aim to provide an electric-power supply unit that can reduce the stress impressed on the switching element immediately after the oscillation of the inverter circuit starts.

[0033] Furthermore, the inventions of the claims 10 through 14 propose to resolve the above-mentioned third problem, and thus aim to provide an electric-power supply unit that can reduce the stress impressed on the switching element of the inverter circuit as concurrently facilitating the simplification of the circuit configuration that reduces said stress.

[0034]

[Means for Resolving the Problems]

In order to achieve the aforesaid purpose, the invention of Claim 1 [provides] an electric-power supply unit comprising a rectifier for rectifying the alternating-current voltage source, a first capacitor connected between the output ends of the rectifier, an inverter circuit provided with a first and a second main switching elements that are series-connected to both ends of the first capacitor as well as a resonant circuit that is parallel-connected to either one of the main switching elements, and a control circuit for alternately switching the first and the

second main switching elements between ON and OFF [states] at high frequency. Said resonant circuit is configured having a first inductance for resonance, a second capacitor for resonance parallel-connected to a load, a third capacitor for coupling direct current, and a fourth capacitor to which the first diode is parallel-connected; and comprising said parallel circuit of the fourth capacitor and the first diode being connected between the first capacitor and the series circuits of the first and the second main switching elements, a series circuit (of the second diode and the fifth capacitor as well as the second inductance) and a sixth capacitor being parallel-connected to the series circuit of the first and the second main switching elements, and the connection point (of the first and the second main switching elements) and the connection point (of the second inductance and the second diode) being connected by the third diode; [Furthermore, according to said electric-power supply unit,] the switching element is provided in parallel to the second diode, while the ON-and-OFF switching of said switching elements carried out by said control circuit according to the state of the load. [Thereby, the invention of Claim 1] enables a so-called "valley infilling" (partial smoothing) of the power-supply voltage of the inverter circuit by turning off said switching elements during normal [conditions], facilitating an improvement of the load current waveform as well as preventing the power-supply voltage of the inverter circuit from increasing by means of turning said switching elements to the ON [state] during light-load [conditions].

[0035] The invention of Claim 2, in order to achieve the aforesaid purpose, [provides] an electric-power supply unit comprising a first capacitor connected to the rectifier, an inverter circuit provided with a first and a second main switching elements series-connected in parallel to the first capacitor as well as a resonant circuit parallel-connected to either one of the main switching elements, and a control circuit for alternately switching the first and the second main switching elements between ON and OFF [states] at high frequency. Said resonant circuit is configured having a first inductance for resonance, a second capacitor for resonance connected in parallel to a load, a third capacitor for coupling direct current, and a fourth capacitor to which the first diode is connected in parallel; and comprising said parallel circuit of the fourth capacitor and the first diode being connected between the first capacitor and the series circuits of the first and the second main switching elements, a series circuit (of the second diode and the fifth capacitor as well as the second inductance) and a sixth capacitor being connected in parallel to the series circuit of the first and the second main switching elements, and the connection point (of the first and the second main switching elements) and the connection point (of the second inductance and the second diode) being

connected by the third diode. Furthermore, said electric-power supply unit is also characterized by being provided with a pair of switching terminals provided at both ends of the second inductance, a common terminal provided at the high-voltage side of the first main switching element, and a switching circuit that, being controlled by said control circuit, alternatively switches and connects said common terminal to said pair of the switching terminals. [Accordingly, the invention of Claim 2] enables a so-called "valley infilling" (partial smoothing) of the power-supply voltage of the inverter circuit by switching the common terminal of said switching circuit to one side of the switching terminals during normal [conditions], facilitating an improvement of the load current waveform as well as preventing the power-supply voltage of the inverter circuit from increasing by means of switching said common terminal of the switching circuit to the other side of the switching terminals during light-load [conditions].

[0036] The invention of Claim 3, in accordance with the invention of Claim 1, is characterized being provided with a switching element for use in short-circuiting between both ends of said fourth capacitor through the ON/OFF switching [operation] thereof carried out by said control circuit; and thereby it is capable of facilitating the prevention of increase in the power-supply voltage of the inverter circuit by turning said switching element to the ON [state] and short-circuiting the fourth capacitor even when the load is at the minimum [<sic> lightest], such as during no-load [states], or in case of other abnormal conditions.

[0037] The invention of Claim 4, in accordance with the invention of Claim 1, is characterized by the series circuit of the switching elements (that is switched between ON and OFF by said control circuit) and the 7th capacitor being parallel-connected to the fourth capacitor. According to [the invention of Claim 4], the 7th capacitor is selectively connected to the fourth capacitor through the ON-OFF operation of said switching element; and the apparent capacity of the fourth capacitor is altered. Accordingly, [the invention of Claim 4] can facilitate the prevention of an increase in the power-supply voltage of the inverter circuit and the reduction of the stress on the main switching elements even when the power supply to the load is limited [<sic> narrowed down].

[0038] The invention of Claim 5, in accordance with the invention of Claim 2, is characterized by being provided with a switching element that short-circuits between both ends of said fourth capacitor through the ON/OFF switching [operation] thereof carried out by said control circuit, and comprising a series circuit of said switching elements (that is switched between ON and OFF by said control circuit) and the 7th capacitor being parallel-connected to the fourth capacitor. [Accordingly, said invention of Claim 5] can facilitate the prevention of

an increase in the power-supply voltage of the inverter circuit by turning said switching element to the ON [state] and short-circuiting the fourth capacitor even when the load is at the minimum [<sic> lightest], such as during no-load [states], or in case of other abnormal conditions. [Furthermore, according to [the invention of Claim 4,] because the 7th capacitor is selectively connected to the fourth capacitor through the ON-OFF operation of said switching element; and the apparent capacity of the fourth capacitor is altered, it can also facilitate the prevention of an increase in the power-supply voltage of the inverter circuit and the reduction of the stress on the main switching elements even when the power supply to the load is limited [<sic> narrowed down].

[0039] The invention of Claim 6, in order to achieve the aforesaid purpose, [provides] an electric-power supply unit provided with a rectifier for rectifying the alternating-current voltage source; an inverter circuit that converts the output of said rectifier into a high frequency output and supplies it to a load, said inverter circuit being provided with one or multiple main switching elements switched at high frequency as well as having a resonant circuit comprising one or multiple inductances for resonance, a capacitor for resonance, a capacitor (which is adapted for cutting the direct-current component) and a load; and a power-supply circuit that is provided with one or multiple capacitors for partial smoothing and performs partial smoothing of the output of said rectifier. [Furthermore, said electric-power supply unit] is [also] characterized by being provided with a feedback means for returning a portion of the high frequency output of said inverter circuit to the output side of the rectifier via said resonant circuit, and a control means for causing the oscillation of said inverter circuit to start when the absolute value of the alternating-current supply voltage is lower than that of the end-to-end voltage of the capacitor (which is adapted for partial smoothing). [According to the invention of Claim 6,] the oscillation of the inverter circuit is started by the control means when the absolute value of the alternating-current supply voltage is lower than that of the end-to-end voltage of the capacitor (which is adapted for partial smoothing), during the power-on state of the alternating-current voltage source. And therefore [the invention of Claim 6] can reduce the stress applied to the main switching elements of the inverter circuit in the process of charging the capacitor (which is adapted for cutting the direct-current component) to the steady state.

[0040] The invention of Claim 7, in accordance with the invention of Claim 6, is characterized by being provided with a means for charging the capacitor (which is adapted for partial smoothing), before the oscillation of said inverter circuit starts. Charging the capacitor (which is adapted for partial smoothing) in advance before the oscillation of the inverter circuit starts can reduce the electric current flowing

into the capacitor (which is adapted for partial smoothing) when the oscillation of the inverter circuit starts. Accordingly, [the invention of Claim 7] can reduce the stress impressed on the main switching elements of the inverter circuit.

[0041] The invention of Claim 8, in accordance with the invention of Claim 7, is characterized by being provided with a means for charging the capacitor (which is adapted for cutting the direct-current component and comprises said resonant circuit) until the end-to-end voltage of the capacitor (which is adapted for cutting the direct-current component) reaches a state lower than the end-to-end voltage of the capacitor (which is adapted for partial smoothing), before the oscillation of said inverter circuit starts, and [therefore] can reduce the stress impressed on the main switching elements of the inverter circuit.

[0042] The invention of Claim 9, in accordance with the inventions of the claims 6 through 8, is provided with a detection means for detecting the zero-cross of the alternating-current supply voltage; wherein said control means is characterized by causing the oscillation of said inverter circuit to start when the detection means detects the zero-cross and thus the end-to-end voltage of the capacitor (which is adapted for cutting the direct-current component) is almost close to zero at a place near the zero cross point of the alternating-current supply voltage. Accordingly, [the invention of Claim 9] is capable of reducing the stress impressed on the main switching elements of the inverter circuit.

[0043] The invention of Claim 10, in order to achieve the aforesaid purpose, [provides] an electric-power supply unit provided with a rectifier for rectifying the alternating-current voltage source; an inverter circuit that is provided with one or multiple main switching elements switched at high frequency and that converts the direct-current output into a high-frequency AC output and supplies it to a load; and a partial smoothing circuit that has one or multiple capacitors as well as inductances, and that supplies, to said inverter circuit, said direct-current output, which was [obtained] by charging said capacitor through the ON-OFF operation of said main switching elements and partially smoothing the pulsating current output of the rectifier. [Furthermore, said electric-power supply unit is [further] characterized by the capacitor of said partial smoothing circuit being series-connected to said main switching elements via the inductance; as well as the charge circuit (for charging said capacitor before the operation of said inverter circuit starts up) being parallel-connected to the series circuit of said inductance and the main switching elements. [Accordingly, the invention of Claim 10] can reduce the stress applied to the main switching elements by the charge circuit when the operation of said inverter circuit starts up; can reduce the voltage impressed on the charge circuit during the inverter circuit operation; can lower the

withstanding voltage of the circuit component used for the charge circuit; and thereby enables the miniaturization and simplification of the charge circuit.

[0044] The invention of Claim 11, in accordance with the invention of Claim 10, is characterized by being configured in such a way that the electric charging [operation of said capacitor] by said charge circuit is discontinued once said capacitor is charged up to or greater than a prescribed level, and therefore is capable of eliminating unnecessary power consumption in the charge circuit. The invention of Claim 12, in accordance with the invention of Claim 11, is characterized by said charge circuit being equipped with an opening-and-closing means that opens and closes the electric charging route of said capacitor. During the operation of the inverter circuit, by setting the opening-and-closing means in the open [state], the electric charging of said capacitor by the charge circuit will no longer be performed. [In this way, the invention of Claim 12] is capable of eliminating the needless electricity consumption for [<sic> by/due to] the charging current.

[0045] The invention of Claim 13, in accordance with the invention of Claim 12, is characterized by said opening-and-closing means starting operation before the main switching elements of the inverter circuit [do], and the ON-OFF operation being repeated in synchronization with the ON-OFF operation of said main switching elements, enabling easier control of [said] opening-and-closing means and thereby facilitating the simplification of the circuit. The invention of Claim 14, in accordance with the invention of Claim 12, is characterized by the ON-OFF operation of said opening-and-closing means being repeated in accordance with the charge-voltage level of said capacitor, thereby enabling easier control of [said] opening-and-closing means and thereby facilitating the simplification of the circuit.

[0046]

[Embodiment of the Invention]

The following is a detailed explanation of the present invention using the embodiments.

(Embodiment 1)

Figure 1 is the schematic circuit diagram showing the first embodiment of the present invention. As shown in Figure 1, the basic configuration of the present embodiment is shared with Conventional Example 1 shown in Figure 35. For this reason, designating the reference coding identical [to that of said example] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the

following includes the explanations only for the characteristic [features] of the present embodiment.

[0047] The present embodiment is characterized by being provided with a switching element Q3 consisting of a field-effect transistor having a parasitic diode Da instead of a diode D0 comprising a chopper circuit CH1 in Conventional Example 1; and having the ON-OFF control of said switching element Q3 configured to be executed by a control circuit CNT1, which controls the drive of the main switching elements Q1 and Q2 of the inverter circuit INV1. It is to be noted that, instead of a field-effect transistor, a bipolar transistor having a diode connected in anti-parallel thereto may be used as the switching element Q3.

[0048] The following is the circuit operation of the present embodiment with reference to the figures 2 through 6. Figure 5 is a time chart that shows each driving signal output from the terminals (1) through (3) of the control circuit CNT1. First of all, for a very short period of time since the time at which the power is turned on (T0), no driving signals are output from terminal (1) and terminal (2) of the control circuit CNT1 and the main switching elements Q1 and Q2 will switch to the OFF [state]; while a driving signal of H-level is output from terminal (3) and the switching element Q3 will switch to the ON [state]. Thereby, as shown in Figure 6, the charging current i0 flows from the rectifier DB via the route of the capacitor C5 → inductance L2 → switching element Q3 → impedance component Z; enabling the preliminary charging of the capacitor C5. In other words, the capacitor C5 comprising a chopper circuit CH1 must be charged before the inverter circuit INV1 is activated at the power-on state; and for that reason, a preliminary charging period T0 as mentioned above has been provided [thereto]. It is to be noted that it is desirable to interpose an impedance component Z, since it lowers the charging current i0 and protect the switching element Q3.

[0049] The control circuit CNT1 turns off the switching element Q3 by setting the terminal (3) at L-level after the completion of said preliminary charging of the capacitor C5. Herein, when the switching element Q3 is OFF, the low-voltage side of the capacitor C6, and the connection point of the inductance L2 and the diode D7 will be connected by the parasitic diode Da of the switching element Q3, and will form exactly the same circuit configuration as that of Conventional Example 1 as shown in Figure 2.

[0050] Then, the control circuit CNT1 outputs driving signals from the terminal (1) and the terminal (2), and alternately switches the main switching elements Q1 and Q2 between ON and OFF at high frequency. The frequency f1 of the driving signals at this time is set at a frequency that is sufficiently higher than the resonance frequency of the resonant circuit RE1, comprising an electric-discharge

lamp La (which is the load), so as to allow the preheating the filament of the electric-discharge lamp La without initiating the electric-discharge lamp La. Accordingly, while such a method can enable light-load [operation], since it does not require the initiation of the electric-discharge lamp La during the precedential pre-heating period T1 for preheating the filament of the electric-discharge lamp La in advance, it can also prevent the voltage step-up of the supply voltage Vdc of the inverter circuit INV1 (which was caused by the increase in the charge voltage of the capacitor C4) by providing a chopper circuit CH1 as described in Conventional Example 1. Furthermore, because the operating frequency f1 of the main switching elements Q1 and Q2 during the precedential pre-heating period T1 is set at higher than the resonance frequency of the resonant circuit RE1, the drain current waveforms of the main switching elements Q1 and Q2 do not comprise the waveforms somewhat indicating a phase-advance [<sic> waveform form close to phase-advance] at the valley section with a low power-supply voltage Vdc (see Figure 49 (c).), but comprises a waveform somewhat indicating a phase-delay [<sic> phase-delay-like waveforms] (see Figure 49 (b)), [thereby] reducing the stress to the main switching elements Q1 and Q2.

[0051] On the other hand, once the electric-discharge lamp La is initiated after preheating, the control circuit CNT1 lowers the frequency of the driving signals from the terminal (1) and the terminal (2), and switches the main switching elements Q1 and Q2 between ON and OFF at the operating frequency f2 set close to the resonance frequency of the resonant circuit RE1. Concurrently, in such a steady-normal illumination period T2, the control circuit CNT1 comprises a circuit configuration as shown in Figure 3 having [said control circuit CNT1] turn on the switching element Q3 by setting the terminal (3) at H-level. In other words, the chopper circuit CH1 no longer connects the anode of the diode D7 as well as the low-voltage side of the inductance L2 to the output end of the low-voltage side (grand line) of the rectifier DB. As a result, the inductance L2 is caused to serve as a choke for cutting the high-frequency current of the capacitor C5; and the resonance regenerative current of the inverter circuit INV1 is made to flow via the capacitor C6, [thereby] comprising a circuit configuration wherein the inductance L2 and the capacitor C6 that comprise the chopper circuit CH1 will lower the ripple current of the capacitor C5.

[0052] Most of the circuit configuration shown in Figure 3 is shared with the one described in JP,5-38161,A. [Said circuit configuration shown in Figure 3] can set [<sic> make] even the power-supply voltage Vdc of the inverter circuit INV1 at a voltage with few ripples as shown in Figure 4, because the ripple current of the capacitor C5 can be lowered at the inductance L2 and the capacitor C6 as

mentioned above; and [therefore] can suppress the drop of the power-supply voltage Vdc at the peak and the valley sections of the power-supply voltage of the alternating-current voltage source AC. Furthermore, the resonance voltage amplitude (which it is generated at both ends of the capacitor C4 of resonant circuit RE1) can be increased by increasing the operating frequency of the main switching elements Q1 and Q2. By so doing, it becomes possible to provide a higher input-power factor as well as to facilitate reduction in the harmonic content of the input current, without causing an idle period of the input current even at the valley section (where the power-supply voltage Vdc is low).

[0053] According to the present embodiment, in case of using an electric-discharge lamp La as the load, a circuit configuration can be selected according to the operation mode of the inverter circuit INV1 (precedential preheating mode for preheating the electric-discharge lamp La in advance, and illumination mode for lighting up the electric-discharge lamp La). In other words, because [the operation] is in a light-load [state] during the precedential preheating mode, the voltage step-up of the supply voltage Vdc of inverter circuit INV1 (which is caused due to the increase in the charge voltage of the capacitor C4) can be prevented by selecting a circuit structure shared with Conventional Example 1, as shown in Figure 2, while setting the switching element Q3 to the OFF [state]. For the illumination mode on the other hand, the stress to the main switching elements Q1 and Q2 can be reduced by selecting a circuit configuration such as shown in Figure 3 while setting the switching element Q3 to the ON [state], since [such a circuit] will cause the drain-current waveforms of the main switching elements Q1 and Q2 to form, at a valley section (where the power-supply voltage Vdc is low), a waveform somewhat indicating a phase-delay [<sic> phase-delay-like waveforms] avoiding the formation of a waveform somewhat indicating a phase-advance [<sic> waveform form close to phase-advance]. Accordingly, there is also another advantage in that [the present embodiment] can allow the optimal design in each circuit configuration selected according to each mode.

[0054] **(Embodiment 2)**

Figure 7 is the schematic circuit diagram showing the second embodiment of the present invention. Most of the basic configuration of the present embodiment is shared with Conventional Example 1 shown in Figure 35, as well. And therefore, designating the reference coding identical [to that of said example] for the shared parts, and the explanation thereof shall be omitted herein. A capacitor C1, which serves as a pseudo power source via a choke coil L0 for cutting the high-frequency current, is connected to both ends of the alternating-current voltage source AC. A

rectifier DB, which consists of a diode bridge, is connected in parallel to the capacitor C1. Hereinafter the circuit comprising choke coil L0, capacitor C1 and rectifier DB shall be referred to as the "power supply circuit PS."

[0055] The resonant circuit RE2 according to the present embodiment is configured with a capacitor C2 for resonance being connected between an inductance L1 for resonance and the cathode of a diode D6 (to which a capacitor C4 for the distortion improvement is connected in parallel); the primary side of a transformer T 1 being connected to the capacitor C2 in parallel; and each filament of electric-discharge lamp La being connected to the secondary side of the transformer T1 in series via capacitors Ca and Cb (which are the impedance components for restricting the preheat current).

[0056] [The present embodiment] is provided with a common terminal s at the drain of the main switching element Q1 at the high-voltage side, which comprises the inverter circuit INV2, a switching terminal p at the output end at the high-voltage side of the rectifier DB, and a switching terminal q at the connection point of the inductance L2 and the capacitor C5, respectively; as well as being [further] provided with a switching circuit SW which alternatively switches and connects said two switching terminals p and q to the common terminal s. This switching circuit SW may be formed as a relay circuit that is driven by the control signals output from the terminal (3) of the control circuit CNT2. Additionally, a diode D9 for returning the resonance current of the inverter circuit INV2 is connected between the connection point of the main switching elements Q1 and Q2, and the output end of the high-voltage side of the rectifier DB.

[0057] The control circuit CNT2 outputs the driving signals from the terminal (1) and the terminal (2), and alternately switches the main switching elements Q1 and Q2 between ON and OFF at high frequency. As a result, a high-frequency resonance current flows into the resonant circuit RE2, and thus high-frequency power is supplied to the electric-discharge lamp La via the transformer T1. Concurrently, by generating a high-frequency voltage to both ends of the capacitor C4 and channeling a high-frequency current to the capacitor C1 (which serves as a pseudo power source) via the rectifier DB, it becomes possible to channel the input current across the entire interval of the power-supply voltage cycle of the alternating-current voltage source AC, and thereby [the present embodiment] can facilitate the improvement of the input-power factor.

[0058] With reference to Figures 8 · 13, the circuit operation of the present embodiment is explained in more detail in the following. The first section of the explanation includes the case where the common terminal s is connected to the switching terminal q by controlling the switching circuit SW with the control

circuit CNT2. In this case, the circuit shown in Figure 7 is switched to the circuit configuration shown in Figure 8. As a result, the inductance L2 is interposed between the drain of the main switching element Q1 and the cathode of the diode D9 for returning the resonance current; and the chopper circuit CH2 is configured with the inductance L2, the capacitor C5, and the diodes D7 and D0 as well as main switching element Q2 at the low-voltage side. This chopper circuit CH2 performs the following operation.

[0059] When the main switching element Q2 turns on with the driving signal from the control circuit CNT2, the resonance current i2 of the inverter circuit INV2, as shown in figure 9, flows via the route of the resonant circuit RE2 → main switching element Q2 → resonant circuit RE2. Furthermore, the regenerative current i3, which was [generated] when the main switching element Q2 turns off, likewise flows via the route of the resonant circuit RE2 → diode D9 → capacitor C6 → resonant circuit RE2, as shown in Figure 9. During this period, a chopper electric current i1 flows into the chopper circuit CH2 via the main switching element Q2. Next, when the main switching element Q2 turns off and the main switching element Q1 turns on, the resonance current i5 flows via the route of the main switching element Q1 → resonant circuit RE2 → diode D0 → capacitor C5, using the capacitor C5 as the power source as shown in Figure 10. The regenerative current i6 at the moment when the main switching element Q1 turns off flows via the parasitic diode (not shown) of the main switching element Q2. And, in the chopper circuit CH2, the energy accumulated in inductance L2 is discharged, and thereby the electric current i4 flows via the route of the inductance L2 → capacitor C5 → diode D7 → diode D9 → inductance L2, so as to charge the capacitor C5.

[0060] Herein, [according to] the chopper circuit CH2 of the present embodiment, the capacitor C5 serving as the power source of the inverter circuit INV2 serves as a voltage-step-down chopper circuit configuration connected to the alternating-current voltage source AC (power supply circuit PS) via the inductance L2; and the end-to-end voltage Vc5 of the capacitor C5 will become a lower voltage than the undulating voltage VPS output from the power supply circuit PS, as shown in Figure 11. Accordingly, a voltage lower than the power-supply voltage of the alternating-current voltage source AC will be impressed on the main switching elements Q1 and Q2, and thereby [the present embodiment] can facilitate miniaturization of the device as well as reduction of the stress to the main switching elements Q1 and Q2.

[0061] On the other hand, when the common terminal s is connected to a switching terminal at another side p by controlling the switching circuit SW with the control circuit CNT2, the circuit shown in Figure 7 is switched to a circuit configuration

identical to Conventional Example 1, shown in Figure 2. Herein, in the circuit configuration shown in Figure 3 of Embodiment 1, since the capacitor C5 (which supplies the power-supply voltage Vdc of the inverter circuit INV1) is provided for the rectifier DB in a latter step than the inverter circuit INV1, there will be no idle period of the input current Iin as shown in Figure 12. However, when attempting to channel the sine-wave input current Iin across the entire interval during one cycle of the alternating-current voltage source AC in this way, the lamp current ILa flowing into the electric-discharge lamp La (which is the load) fluctuates to become greater at the valley area, and to become smaller at the peak area according to the fluctuation of the input current Iin, causing malfunctions such as a decline in the luminous efficiency of the electric-discharge lamp La. On the other hand, by adopting the circuit configuration as shown in Figure 2, the power-supply voltage Vdc of the inverter circuit INV1 will form a voltage waveform that will be low at the valley section and high at the peak section, of the pulsating-current output voltage of the rectifier DB. As a result, the lamp current ILa can be made to form a waveform with less ripple that may have the peaks at both of the valley and the peak sections of the input current Iin, as shown in Figure 13.

[0062] Accordingly, the present embodiment can provide benefits as follows:

With a configuration using an electric-discharge lamp La as the load, it can facilitate an improvement in efficiency of the electric-discharge lamp La by connecting a common terminal s to a switching terminal at another side p through the control of a switching circuit SW using a control circuit CNT2 when lighting up [the lamp] (illumination mode); and during a light-load [state] such as during the execution of the precedential preheating (in the precedential preheating mode), during the start-up (in the initiation mode), or at the end of service life, etc., it can reduce the supply voltage of an inverter circuit INV2 as well as the stress and the withstanding voltage of the main switching elements Q1 and Q2, by configuring the voltage step-down chopper circuit CH2 connecting the common terminal s to a switching terminal at another side q through the control of the switching circuit SW using the control circuit CNT2.

[0063] (Embodiment 3)

Figure 14 is the schematic circuit diagram showing the third embodiment of the present invention. Most of the basic configuration of the present embodiment is shared with the embodiments 1 and 2. Therefore, designating the reference coding identical [to that of said example] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment. [0064] The present

embodiment is characterized by being provided with a chopper circuit CH1 shared with Embodiment 1, and an inverter circuit INV3 having a resonant circuit RE3 having a switching element Q4 comprising a FET (instead of the diode D6 in the resonant circuit RE2 according to Embodiment 2) parallel-connected to the capacitor C4; wherein, the ON-OFF [operation] of the switching element Q4 is controlled by the control signals output from the terminal (4) of the control circuit CNT3.

[0065] When both switching elements Q3 and Q4 are turned on by the control circuit CNT3, the present embodiment comprises an circuit configuration equivalent to [<sic> equivalently] the configuration as shown in Figure 15. As explained in Embodiment 1, when the switching element Q3 is turned on, the chopper circuit CH1 is no longer formed because the low-voltage side of the anode of the diode D7 as well as the inductance L2 is connected to the output end of the low-voltage side of the rectifier DB (grand line). As a result, the inductance L2 serves as a choke for cutting the high-frequency current of the capacitor C5; the resonance regenerative current of the inverter circuit INV3 flows via the capacitor C6; and the ripple current of the capacitor C5 is reduced by the inductance L2 and the capacitor C6. On the other hand, because both ends of the capacitor C4 will be bypassed by the switching element Q4 when the switching element Q4 is turned on, the effect of the capacitor C4 of improving the input-current distortion is no longer obtained. However, with this circuit configuration, because the pulsating-current output voltage of the rectifier DB shown in Figure 16 is smoothed by the capacitor C5 and supplied to the inverter circuit INV3, the power-supply voltage Vdc of inverter circuit INV3 does not increase to a higher [level] than the power-supply voltage of the alternating-current voltage source AC. Therefore, it can provide the benefit that withstanding the voltage of the main switching elements Q1 and Q2 can be managed at the level of the power-supply voltage of the alternating-current voltage source AC.

[0066] Additionally, in the event that the control circuit CNT3 turns on the switching element Q3 and turns off the switching element Q4, the chopper circuit CH1 is comprised of a circuit configuration equivalent to [<sic> equivalently] the configuration as shown in Figure 17. Accordingly, the power-supply voltage Vdc of the inverter circuit INV3 (the end-to-end voltage of the capacitor C5) forms a waveform whose valley part has been infilled (which is partially-smoothed) by the chopper circuit CH1 as shown in Figure 18. [Thereby,] the voltage step-up of said power-supply voltage Vdc can be prevented in all operation modes (precedential preheating mode, steady-normal illumination mode, etc.) of the inverter circuit INV3. Furthermore, the formation of the chopper circuit CH1 provides the effect of

improving the input-current distortion more or less in comparison with the circuit configuration shown in Figure 15, as well as the effect of providing higher efficiency. Nevertheless, it cannot be denied that the luminous efficiency of the electric-discharge lamp La will drop because of the lamp current ILa flowing into the electric-discharge lamp La (which is the load) fluctuating in such a way that it may become greater at the valley, and smaller at the peak, of the power-supply voltage Vdc. It is to be noted that, when the switching element Q4 is in the OFF [state], the configuration of the resonant circuit RE3 becomes identical to the configuration of the resonant circuit RE2 of Embodiment 2 with the parasitic diode Dx of the switching element Q4. Accordingly, the resonance voltage generated at both ends of the capacitor C4 does not allow the occurrence of an idle period of the input current even at the valley section (where the power-supply voltage Vdc is low), and achieves a high input-power factor as well as facilitating reduction of the harmonic content of the input current.

[0067] The present embodiment, when using an electric-discharge lamp La as the load, can prevent the voltage step-up of the power-supply voltage Vdc of the inverter circuit INV1 and reduce the stress to the main switching elements Q1 and Q2, by switching the circuit configuration through ON-OFF [operation] of the switching element Q3 in the precedential preheating mode and the illumination mode. It can also facilitate the prevention of a voltage step-up of the power-supply voltage Vdc even when the load is at the minimum [<sic> lightest], such as during a no-load [state], or in case of other abnormal conditions, etc., and provide the benefit of enabling [features] to support various operation modes

[0068] (Embodiment 4)

Figure 19 is the schematic circuit diagram showing the fourth embodiment of the present invention. Most of the basic configuration of the present embodiment is shared with the embodiments 1 and 2. Therefore, designating the reference coding identical [to that of said embodiments] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment.

[0069] The present embodiment is characterized by being provided with a chopper circuit CH1 shared with Embodiment 1, and an inverter circuit INV4 having a resonant circuit RE4 connecting a series circuit of the switching element Q5 (which consists of a capacitor C7 and a FET) in parallel to the capacitor C4 and the diode D6 of the resonant circuit RE2 according to Embodiment 2; wherein the ON-OFF [operation] of the switching element Q5 is controlled by the control signal output from a terminal (5) of the control circuit CNT4. In other words, in case of using an

electric-discharge lamp La as the load in Embodiment 1, the electric charging period of the distortion-improvement capacitor C4 becomes shorter than that in the steady-normal illumination mode when turning on [the lamp] with modulated/dimmed light lowering the optical power of the electric-discharge lamp La while increasing the drive frequency of the main switching elements Q1 and Q2 using the control circuit CNT1 (dimmed-illumination mode). Consequently, the capacitor C4 will not be charged sufficiently at the valley section of the power-supply voltage VAC of the alternating-current voltage source AC, resulting in an idle interval in the input-current waveform as shown in Figure 20 (a). Given this factor, the present embodiment provides a means (capacitor C7 and switching element Q5) for altering the apparent capacity of the capacitor C4, in order to resolve such a malfunction. Therefore, by turning on the switching element Q5 while setting the terminal (5) of the control circuit CNT4 at the H-level in the above-mentioned dimmed-illumination mode, the capacitor C7 is parallel-connected to the capacitor C4; and the apparent capacity of the capacitor C4 increases (comprises the synthetic capacity combining the capacity C4 and the capacity C7 of the capacitor C7). Accordingly, the input current Iin can be channeled across the approximately entire interval of the power-supply voltage VAC without causing an idle period as shown in Figure 20 (b).

[0070] Meanwhile in the dimmed-illumination mode, the supply power to the electric-discharge lamp La is reduced by increasing the drive frequency of the main switching elements Q1 and Q2. This results in a lighter load than in the steady-normal illumination mode, which [then] could lead to an increase in the end-to-end voltage of the capacitor C4 (parallel circuit of the capacitor C4 and the capacitor C7). However, a chopper circuit CH1 is formed by turning off the switching element Q3 in the control circuit CNT4 during the dimmed-illumination mode and the power-supply voltage Vdc supplied to the inverter circuit INV4 is valley-infilled (partially smoothed); making it possible to prevent the power-supply voltage Vdc from stepping up as explained in Embodiment 1. Meanwhile in the dimmed-illumination mode, given that the drive frequency of the main switching elements Q1 and Q2 is set higher than the resonance frequency of the resonant circuit RE4, the drain-current waveforms of the main switching elements Q1 and Q2 do not form a waveform somewhat indicating a phase-advance [<sic> waveform form close to phase-advance] at the valley section (where the power-supply voltage Vdc is low); instead it forms a waveform somewhat indicating a phase-delay [<sic> phase-delay-like waveforms] [at the valley section], and [thereby] the stress to the main switching elements Q1 and Q2 can be reduced.

[0071] The present embodiment can [therefore] facilitate the prevention of an

increase in the power-supply voltage Vdc of the inverter circuit INV4 and the reduction the stress to the main switching elements Q1 and Q2, even when turning on the electric-discharge lamp La (which is the load) with a dimmed-light in Embodiment 1.

(Embodiment 5)

Figure 21 is the schematic circuit diagram showing the fifth embodiment of the present invention. Most of the basic configuration of the present embodiment is shared with Embodiment 2. Therefore, designating the reference coding identical [to that of said embodiments] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment.

[0072] The present embodiment is characterized by being provided with a resonant circuit RE5 parallel-connecting a switching element Q4, as explained in Embodiment 3, as well as a series circuit of the switching element Q5 and a capacitor C7, as explained in Embodiment 4, to the capacitor C4, instead of the diode D6 of the resonant circuit RE2 in Embodiment 2, wherein the ON-OFF [operation] of each of the switching elements Q4 and Q5 is controlled by the control signals output from the terminal (5) and the terminal (6) of the control circuit CNT5.

[0073] In other words, when using an electric-discharge lamp La as the load, by turning on the switching element Q5 while setting the terminal (5) of the control circuit CNT4 at the H-level in the dimmed-illumination mode as explained in Embodiment 4, the capacitor C7 is parallel-connected to the capacitor C4 and the apparent capacity of the capacitor C4 increases; and accordingly, the input current Iin can be channeled across the approximately entire interval of the power-supply voltage VAC without causing an idle period. Furthermore, as explained in Embodiment 3, by switching the switching element Q4 to the ON [state] and short-circuiting the capacitor C4 as well as the series circuit of the capacitor C7 and the switching element Q5, the power-supply voltage Vdc can be prevented from stepping up even in case when the load is at the minimum [<sic> lightest], such as during a no-load [state], or in case of other abnormal conditions, etc. Moreover, the efficiency of electric-discharge lamp La can be improved by connecting the common terminal s to the switching terminal p at another side by controlling the switching circuit SW using the control circuit CNT5 while the lamp is on (in the illumination mode) as explained in Embodiment 2; whereas, during a light-load [state], such as during the execution of a precedential preheating (in the precedential preheating mode), during the start-up (in the initiation mode), or at

the end of service life, etc., the stress and the withstanding voltage of the main switching elements Q1 and Q2 can be reduced given that a deeper level of dimming [effect] becomes available through the lowering of the supply voltage of the inverter circuit INV5, which is achieved by configuring the voltage-step-down chopper circuit CH2 after connecting the common terminal s to switching terminal q at another side controlling the switching circuit SW by the control circuit CNT5.

[0074] (Embodiment 6)

Figure 22 is the schematic circuit diagram showing the sixth embodiment of the present invention. As shown in Figure 22, the basic configuration of the present embodiment is shared with Conventional Example 3 shown in Figure 39. Therefore, designating the reference coding identical [to that of said example] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment.

[0075] The present embodiment is characterized by being provided with a starting circuit 2, which detects the zero-cross point of the power-supply voltage VAC of the alternating-current voltage source AC, and which outputs seizure signals to the control circuit CNT6 in such a way that the oscillation movement of the inverter circuit INV6 starts in the vicinity of the zero-cross point, [as an addition] to the configuration of Conventional Example 3. In addition, beside [the above-mentioned], [the present embodiment] differs from Conventional Example 3 in having been further provided with a diode D11 connected between the anode of the diode D7 and the capacitor C3 (for cutting the direct-current components); and a diode D10 is connected from the cathode of the diode D7 in parallel to the series circuit of the inductance L2 and the capacitor C5.

[0076] As explained in Conventional Example 3, the resonance system of the inverter circuit INV6 is altered depending on the size of the alternating-current supply voltage VAC. In other words, at the near-peak of the alternating-current supply voltage VAC, a resonance system consists of an inductance L1, a capacitor C2, the primary winding n1 of a transformer T1, and an electric-discharge lamp La. At the near-valley of the alternating-current supply voltage VAC, a resonance system consists of an inductance L1, a capacitor C2, the primary winding n1 of a transformer T1, and an electric-discharge lamp La as well as a capacitor C4. Herein, Figure 23 shows the waveform chart of the end-to-end voltage Vc4 of the capacitor C4 and the end-to-end voltage Vc3 of the capacitor C3 during steady normal operation of the inverter circuit INV6 (for example, when lighting up the electric-discharge lamp La of the load circuit 3 to the full capacity). The following is

an explanation of the circuit operation of the present embodiment with reference to this figure. It is to be noted that said figure (a) shows the waveform of the end-to-end voltage Vc6 of the capacitor C6;
said figure (b) shows the waveform of the end-to-end voltage Vc4 of the capacitor C4; and said figure (c) shows the waveform of the end-to-end voltage Vc3 of the capacitor C3, respectively.

[0077] First, at the peak of the alternating-current supply voltage VAC (near-peak of voltage Vc6), operation of the inverter circuit INV6 is as follows:
When the main switching element Q1 is off and Q2 is on, the resonance current flows from the alternating-current voltage source AC via the route of the rectifier DB→ capacitor C2 and the primary winding n1 of the transformer T1 → inductance L1 → capacitor C3 → main switching element Q2 → rectifier DB → alternating-current voltage source AC. When the main switching element Q1 is on and Q2 is off, the resonance current, using the capacitor C3 as the power source, flows via the route of the inductance L1 → capacitor C2 and the primary winding n1 of the transformer T1 → diode D6 → main switching element Q1 → diode D11 → capacitor C3.

[0078] On the other hand, at the valley section of the alternating-current supply voltage VAC (valley-infilled part of voltage Vc6), when the main switching element Q1 is off and Q2 is on, the resonance current, using the capacitor C5 of the valley-infill power supply circuit 1 as the power source, flows via the route of the capacitor C5 → inductance L2 → diode D0 → capacitor C4 → capacitor C2 and the primary winding n1 of the transformer T1 → inductance L1 → capacitor C3 → main switching element Q2 → capacitor C5. When the main switching element Q1 is on and Q2 is off, the resonance current, using the capacitor C4 as the power source, flows via the route of the main switching element Q1 → diode D11 → capacitor C3 → inductance L1 → capacitor C2 and the primary winding n1 of the transformer T1 → capacitor C4. In this way, at the near-peak of the alternating-current supply voltage VAC, the capacitor C4 is not included in the route through which the resonance current of the inverter circuit INV6 flows; while, at the near-valley, the capacitor C4 is included in said route. To put it differently, the capacitor C4 is included in the resonance system near the valley section of the alternating-current supply voltage VAC.

[0079] Here, the capacity of the capacitor C4 is set at a value that is small enough, in fact smaller than the capacity of the capacitor C3 (for cutting the direct-current components) (C3>>C4). Accordingly, the end-to-end voltage Vc4 of the capacitor C4 forms a waveform impressed with the direct-current component and having high amplitude at the valley section of the alternating-current supply voltage VAC, as

shown in Figure 23 (b). On the other hand, the end-to-end voltage Vc3 of the capacitor C3 forms a waveform wherein, when the direct-current component is being impressed on the end-to-end voltage Vc4 of the capacitor C4 at the valley section of the alternating-current supply voltage VAC, it will cause the voltage value to gradually drop at the valley section of the alternating-current supply voltage VAC and become approximately zero at the zero-cross point of the alternating-current supply voltage VAC, as shown in Figure 23 (c). This is caused by the capacitor C4 with a smaller capacitance value [being forced] to bear said direct-current component.

[0080] As is clear from the above-mentioned [description], at the zero-cross point of the alternating-current supply voltage VAC, the end-to-end voltage Vc3 of the capacitor C3 (for cutting the direct-current components) will be approximately zero; and the capacitor C3 will not affect operation of the inverter circuit INV6. In other words, starting the oscillation movement of the inverter circuit INV6 at the zero-cross point of the alternating-current supply voltage VAC will allow elimination of the problem of Conventional Example 3 (namely, the problem of stress being impressed upon the main switching elements Q1 and Q2 during the process of charging the capacitor C3 to a steady state).

[0081] Given this factor, the present embodiment is provided with a starting circuit 2, which detects the zero-cross point of the power-supply voltage VAC of the alternating-current voltage source AC, and which outputs a seizure signal to the control circuit CNT6 to start the oscillation movement of the inverter circuit INV6 in the vicinity of the zero-cross point; so as to cause the control circuit CNT6 to start the oscillation movement of the inverter circuit INV6 when the seizure signal from the starting circuit 2 is received. [0082] Figure 24 is the overall configuration diagram of the present embodiment showing an example of the concrete circuit configuration of the starting circuit 2. Item 4 is a control power source circuit which supplies the operation power of the starting circuit 2 as well as the control circuit CNT6. [It] obtains the direct-current actuating power by converting the pulsating-current output voltage of the rectifier DB into a constant voltage via a resistor R1 using a zener diode ZD1, and smoothening [it] with a smoothing capacitor C11.

[0083] The starting circuit 2 is provided with a rectifier DB2 that full-wave rectifies the alternating-current supply voltage VAC, voltage dividing resistors R2 and R3 that divide the pulsating-current output voltage of the rectifier DB2, voltage dividing resistors R4 and R5 that divide the direct-current output voltage of the control power source circuit 4, an open-collector-type comparator CP1 that compares these divided voltage signals, a time constant circuit of a capacitor C12

and a resistor R7 series-connected between the output ends of the control power source circuit 4, voltage dividing resistors R8 and R9 that divide the direct-current output voltage of the control power source circuit 4, a comparator CP2 that compares the voltage signals generated at both ends of the capacitor C12 and the voltage signals divided by the voltage dividing resistors R8 and R9, and a switching element Q6 that is connected between the grand line and the output end of the comparator CP2 and turned on and off by the control circuit CNT6. [Additionally, according to the starting circuit 2,] the output signals from said two comparators CP1 and CP2 are input into the control circuit CNT6. It is to be noted that the output end of the comparator CP1 is connected via the resistor R6 to the output end of the high-voltage side of the control power source circuit 4.

[0084] The voltage signals divided at the voltage dividing resistors R2 and R3 will be proportionate to the pulsating-current output voltage of the rectifier DB2, input into the inverting terminal of the comparator CP1. Additionally, the voltage signals divided at the voltage dividing resistors R4 and R5 are virtually-constant voltage signals [obtained] by dividing the direct-current output voltage of the control power source circuit 4, and input into the non-inverting terminal of the comparator CP1. Accordingly, the comparator CP1 compares the voltage signals proportionate to the pulsating-current output voltage of the rectifier DB2 [obtained] through the full-wave rectification of the alternating-current supply voltage VAC (detection signals), with the virtually-constant voltage signals [obtained] by dividing the direct-current output voltage of the control power source circuit 4, and it outputs an L-level signal when the detection signal level is greater than the reference signal level and outputs an H-level signal when smaller. Thus, the zero-cross point of the alternating-current supply voltage VAC can be detected by setting the value of resistance for each voltage dividing resistors R1-R4 so that the output of the comparator CP1 is inverted in the vicinity of the zero-cross [point] of the alternating-current supply voltage VAC.

[0085] Meanwhile, the voltage signals (reference signals) divided by the voltage dividing resistors R8 and R9 are input into the inverting terminal of the comparator CP2. The voltage signal (delay signal) generated at both ends of the capacitor C12 (which comprises the time constant circuit) is input into the non-inverting terminal. An H-level signal is output from the output end of the comparator CP2 when the delay signal level is greater than the reference signal level; whereas, an L-level signal is output therefrom when said delay signal level is smaller than said reference signal level. In other words, the charging process of the smoothing capacitor C11 of the control power source circuit 4 begins immediately after the power of the alternating-current voltage source AC is turned on.

Moreover, since the signals input into the non-inverting terminal of comparator CP2 are delayed by the time constant circuit of the capacitor C12 and the resistor R7, the output of the comparator CP2 is maintained at the L-level for a while after the power is turned on; and therefore, the output signals from the starting circuit 2 will become L-level [signals] regardless of the output of the comparator CP1. However, when the pulsating-current output voltage of the rectifier DB approaches the zero-cross point, because the delay signal input into the non-inverting terminal of the comparator CP2 becomes greater than the reference signal divided by the voltage dividing resistors R8 and R9, the output of the comparator CP2 switches from the L-level to the H-level. And then, when the pulsating-current output voltage of the rectifier DB reaches the zero-cross point, the output of the comparator CP1 switches from the L-level to the H-level; and the output signals of the starting circuit 2 also switches to the H-level since, at this time, the output end of the comparator CP2 is also in the H-level. In other words, immediately after the power of the alternating-current voltage source AC is turned on, the starting circuit 2 outputs an H-level signal (seizure signal) to the control circuit CNT6 only in the vicinity of the zero-cross of the alternating-current supply voltage VAC

[0086] Meanwhile, the control circuit CNT6 starts outputting control signals (driving signals for switching the main switching elements Q1 and Q2 between ON and OFF) to the inverter circuit INV6 using the H-level signal (seizure signal) from the starting circuit 2 as the trigger signal, and also prohibits the input of the seizure signal from the starting circuit 2 by outputting the signal that causes the switching element Q6 of the starting circuit 2 to be in the ON [state]. Here, the time from the point at which the power is turned on until the point at which the oscillation of the inverter circuit INV6 starts is determined by the time constant of said time constant circuit that forms the starting circuit 2 (the value determined by the resistance value of the resistor R7 and the capacitance value of the capacitor C12), and therefore can be controlled by changing the time constant. It is to be noted that the operation of the inverter circuit INV6 after starting the oscillation shall be omitted herein since it has already been described [in the foregoing].

[0087] The present embodiment is provided with a starting circuit 2, which outputs a seizure signal only at the zero-cross point of the alternating-current supply voltage VAC immediately after the power of the alternating-current voltage source AC is turned on, wherein the control circuit CNT6 of the inverter circuit INV6 uses the seizure signal from the starting circuit 2 as the trigger signal to cause the oscillation of the inverter circuit INV6 to start. Thus, [according to the present embodiment,] the oscillation of the inverter circuit INV6 can be started at the zero-cross point of the alternating-current supply voltage VAC; and therefore, the

stress impressed on the main switching elements Q1 and Q2 can be reduced during the process of charging the capacitor C3 without needing to charge the capacitor C3 (capacitor for cutting the direct current of the inverter circuit INV6).

[0088] (Embodiment 7)

Figure 25 is the schematic circuit diagram showing the seventh embodiment of the present invention. As shown in Figure 25, the basic configuration of the present embodiment is shared with Embodiment 6. Therefore, designating the reference coding identical [to that of said embodiment] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment. The present embodiment is different from Embodiment 6 in having the capacitor C13 connected between the pulsating-current output ends of the rectifier DB which consists of the diode bridge; having the diode D12 interposed, with the anode at the rectifier DB side, between the inverter circuit INV6 and one end of the high-voltage side of the capacitor C13, and taking the detection signal of the starting circuit 2 from the connection point of the capacitor C13 and the anode of the diode D12. Herein, the capacitance value of the capacitor C13 is set sufficiently smaller than the capacitance value of the capacitor C5, which comprises the power supply circuit 1; therefore, there is almost no effect of the capacitor C13 on the detection signal input into the starting circuit 2, the detection voltage will be an undulating voltage [obtained through] the full-wave rectification of the alternating-current supply voltage VAC in the same way as in Embodiment 61. Thus, in the same way as in Embodiment 6, [the present invention] can start the oscillation of the inverter circuit INV6 at the zero-cross point of the alternating-current supply voltage VAC when the power of the alternating-current voltage source AC is turned on; and thereby, it is possible to reduce the stress impressed on the main switching elements Q1 and Q2.

[0089] Meanwhile, with the capacitor C13 and the diode D12, which are characteristic of the present embodiment, [the present invention] can reduce the current amount of the high-frequency current of the inverter circuit INV6 that is returned to the rectifier DB; thus, the present embodiment is capable of reducing the heat generation volume generated by the high frequency current flowing into the diode (which comprises the rectifier DB).

(Embodiment 8)

Figure 26 is the schematic circuit diagram showing the eighth embodiment of the present invention. As shown in Figure 26, most of the basic configuration of the

present embodiment is shared with Embodiment 6. Therefore, designating the reference coding identical [to that of said embodiment] for the shared parts, the explanation thereof shall be omitted herein.

[0090] In the inverter circuit INV7 of the present embodiment, while the load circuit 3 is connected in parallel with the main switching element Q2 at the low-voltage side in the same way as in Embodiment 1, the parallel circuit of the capacitor C4 and the diode D6 is interposed in the low-voltage side between the load circuit 3 and the main switching element Q2 as well. It is to be noted that, because the basic operation of the inverter circuit INV7 is the same as that of Embodiment 1, the explanation thereof shall be omitted herein.

[0091] Additionally, in the power supply circuit 4 of the present embodiment, the relationship of the connection between the diode D0 and the series circuit of the capacitor C5 and the inductance L2 is the opposite of that in Embodiment 6 or 7. Furthermore, a switching element Q7, which consists of a FET, is interposed between the output end at the low-voltage side of the rectifier DB (grand line) and the connection point of the main switching elements Q1 and Q2. This switching element Q7 is switched between ON and OFF by the signals from the starting circuit 2.

[0092] Next, the circuit operation at the time when the oscillation of the inverter circuit INV7 starts, according to the present embodiment, is explained with reference to the time chart of Figure 27. It is to be noted that the diagram (a) in Figure 27 depicts the alternating-current supply voltage VAC; the diagram (b) depicts an end-to-end voltage Vc6 of the capacitor C6; the diagram (c) depicts an end-to-end voltage Vc5 of the capacitor C5; the diagram (d) depicts a driving signal of the switching element Q7 output from the starting circuit 2; the diagram (e) depicts a seizure signal output from the starting circuit 2 to control circuit CNT6; and the diagram (f) depicts a driving signal output from control circuit CNT6 to the main switching elements Q1 and Q2.

[0093] When the alternating-current voltage source AC is turned on at time (TOD) t=t0, an H-level driving signal is output from the starting circuit 2 to the switching element Q7, and the switching element Q7 is switched ON (See Figure 27 (d)). And the capacitor C5 of the power supply circuit 4 is charged with the charging current that flows via the route of the rectifier DB→ inductance L2 → capacitor C5 → diode D7 → resistor R11 → switching element Q7 → diode D6 → rectifier DB (See said Figure (c)).

[0094] When the end-to-end voltage Vc5 of the capacitor C5 is charged until it reaches a predetermined level at time (TOD) t=t1, the driving signal from the starting circuit 2 to the switching element Q7 switches to the L-level; while the

seizure signal is output from the starting circuit 2 to control circuit CNT6 in the vicinity of the zero-cross of the alternating-current supply voltage VAC in the same way as in Embodiment 6 or 7 (see said Figures (a) and (e)), triggering the control circuit CNT6, which then outputs a high-frequency driving signal to the main switching elements Q1 and Q2 from the point of time (TOD) t=t2 and starts the oscillation operation of the inverter circuit INV7 (see said Figure (f)).

[0095] And then, because the present embodiment is provided with a means for charging the capacitor C5 of the power supply circuit 4 before starting the oscillation of the inverter circuit INV7 (resistor R11 and the switching element Q7), it can reduce the electric current that flows into the inductance L2 and the capacitor C5 when the oscillation of the inverter circuit INV6 starts, by charging the capacitor C5 in advance before the start of said oscillation. Thereby, it can shorten the discharge period of the energy accumulated in the inductance L1, and reduce the stress impressed on the main switching elements Q1 and Q2 of the inverter circuit INV6.

[0096] Meanwhile, before the oscillation of the inverter circuit INV6 starts (when it is in a halt state), because the capacitor C3 (for cutting direct-current components of the inverter circuit INV6) is connected in parallel to the resistor R11 in a serial-flow relationship, a voltage approximately equal to the voltage drop in resistor R11 is impressed [thereon] at this point. Additionally, before the oscillation of the inverter circuit INV6, the end-to-end voltage Vc5 of the capacitor C5 rises up to a predetermined value (=V1); and when the alternating-current supply voltage VAC is greater than the said predetermined value V1, the electric current flows from the alternating-current voltage source AC via the route of the rectifier DB→ inductance L2 → capacitor C5 → diode D7 → resistor R11 → switching element Q7 → diode D6 → rectifier DB. Therefore, because of the voltage drop in the resistor R11, the voltage is generated also at both ends of the capacitor C3. On the other hand, when the alternating-current supply voltage VAC is smaller than the said predetermined value V1, there will be no route through which the electric current can flow from the alternating-current voltage source AC into the power supply circuit 4 or the inverter circuit INV6; and thus the end-to-end voltage Vc3 of the capacitor C3 becomes approximately zero.

[0097] Accordingly, because the present embodiment starts the oscillation of the inverter circuit INV7 detecting the zero-cross of the alternating-current supply voltage VAC in the starting circuit 2, it can reduce the stress on the main switching elements Q1 and Q2 in the power-on state just as in Embodiment 6 or 7. And in addition thereto, [the present invention] can also reduce the stress on the main switching elements Q1 and Q2 [more] in comparison with the conventional

examples 2 and 3, because it allows the flow of the resonance current of the inverter circuit INV7 via the capacitor C4 even in the event that the oscillation of the inverter circuit INV7 starts when the alternating-current supply voltage VAC is low relative to the end-to-end voltage Vc5 of the capacitor C5 prior to when the oscillation the inverter circuit INV7 starts (for example, predetermined value V1).

[0098] (Embodiment 9)

Figure 28 is the schematic circuit diagram showing the ninth embodiment of the present invention. As shown in Figure 28, most of the basic configuration of the present embodiment is shared with the embodiments 6 and 8. Therefore, designating the reference coding identical [to that of said embodiments] for the shared parts, the explanation thereof shall be omitted herein. In the inverter circuit INV8 of the present embodiment, a load circuit 3 is connected in parallel with the main switching element Q1 at the high-voltage side in the same way as in Embodiment 6. And, in the power supply circuit 5, a series circuit of the capacitor C5 and the inductance L2 is parallel-connected to the main switching element Q1 at the high-voltage side, and a diode D0 is parallel-connected to the main switching element Q2 at the low-voltage side, respectively; while a means for charging the capacitor C5 of the power supply circuit 4 before starting the oscillation of the inverter circuit INV8 (a series circuit of a resistor R11 and a switching element Q7) is parallel-connected to the diode D0. And the resistors R12 and R13 are connected in parallel to the capacitor C3 (which is adapted for cutting the direct-current component) and diode D7. It is to be noted that, because the basic operation of the inverter circuit INV8 is the same as in the embodiments 6 through 8, the explanation thereof shall be omitted herein.

[0099] On the other hand, before the oscillation of the inverter circuit INV8 starts, the switching element Q7 is turned on by the starting circuit 2 and the capacitor C5 of the power supply circuit 5 is charged, in the same way as in Embodiment 8. Here, because the configuration of the load circuit 3 is shared with the embodiments 6 through 8, no direct-current impedance component is present in the load circuit 3. Therefore, the capacitor C5 will be connected in parallel for the series circuit of the two resistors R12 and R13. Additionally, because the capacitor C3 is parallel-connected to the resistor R12, the end-to-end voltage Vc3 of the capacitor C3 will be at the level [equivalent to] the divided voltage of the end-to-end voltage Vc5 of the capacitor C5 (which was divided by the resistors R12 and R13), even when it is at the highest level.

[0100] Given this factor, by starting the oscillation of the inverter circuit INV8 when the end-to-end voltage Vc3 of the capacitor C3 is low relative to the

end-to-end voltage Vc5 of the capacitor C5 before the oscillation of the inverter circuit INV8 starts, and when the end-to-end voltage Vc5 of the capacitor C5 is higher than the alternating-current supply voltage VAC in the same way as Embodiment 8, it becomes possible to reduce the stress applied to the main switching elements Q1 and Q2 at the start of the oscillation of the inverter circuit INV8, even when the capacitor C3 is charged before the oscillation of the inverter circuit INV8 starts. Of course, to start the oscillation of the inverter circuit INV8, a seizure signal may be output from the starting circuit 2 in the vicinity of the zero-cross of the alternating-current supply voltage VAC, in the same way as the embodiments 6 through 8.

[0101] (Embodiment 10)

Figure 29 is the schematic circuit diagram showing the tenth embodiment of the present invention. As shown in Figure 29, most of the basic configuration of the present embodiment is shared with Embodiment 6. Therefore, designating the reference coding identical [to that of said embodiment] for the shared parts, the explanation thereof shall be omitted herein. The present embodiment differs from Embodiment 6 in the configuration of the power supply circuit 6. That is, the power supply circuit 6 of the present embodiment comprises a series circuit of a diode D13, a capacitor C15 and a capacitor C14 connected between the pulsating-current output ends of a rectifier DB via a diode D6, a diode D14 connected in anti-parallel to the capacitor C14 and the diode D13, and a diode D15 connected in anti-parallel to the capacitor C15 and the diode D13. And the capacitors C14 and C15 are charged via the diode D13 near the peal of the alternating-current supply voltage VAC. The end-to-end voltages Vc14 and Vc15 of the respective capacitors C14 and C15 will be approximately half of the peak value of the alternating-current supply voltage VAC when the capacitance value of the capacitor C14 and C15 are about equal. When the alternating-current supply voltage VAC is lower than the end-to-end voltages Vc14 and Vc15 of the respective capacitors C14 and C15, the charging electric charge of the capacitor C14 is discharged via the diode D15; and the charging electric charge of the capacitor C15 is discharged via the diode D14, respectively. Accordingly, this power supply circuit 6 serves as a partial-smoothing power source that partially-smoothes (infills the valley section of) the pulsating-current output voltage of the rectifier DB and supplies it to the inverter circuit INV9.

[0102] Meanwhile in the inverter circuit INV9 of the present embodiment, a series circuit of a zener diode ZD2, a resistor R11 and a switching element Q7 is connected in parallel to the main switching element Q2 at the low-voltage side.

In the same way as in the embodiments 8 and 9, the switching element Q7 is turned on by the starting circuit 2 before the oscillation of the inverter circuit INV9 starts. Given that there is no direct-current impedance component in the load circuit 3, the capacitor C3 is charged via the zener diode ZD2 and the resistor R11 [triggered] by the switching element Q7 turning on. Moreover, the end-to-end voltages Vc14 and Vcb15 of the capacitors C14 and C15 of the power supply circuit 6 will be about equal, indicating approximately half of the peak value of the alternating-current supply voltage VAC as mentioned above.

[0103] Given this factor, the present embodiment can allow the resonance current of the inverter circuit INV9 to flow via the capacitor C4, by setting the zener voltage of the zener diode ZD2 in such a way that the end-to-end voltage Vc3 of the capacitor C3 will become lower than approximately half of the peak value of the alternating-current supply voltage VAC, as well as by starting the oscillation of the inverter circuit INV9 when the alternating-current supply voltage VAC is lower than the end-to-end voltages Vc14 and Vc15 of the capacitors C14 and C15. As a result, the present embodiment can reduce the stress that is applied on the main switching elements Q1 and Q2 at the time of the start of the oscillation of the inverter circuit INV9.

[0104] (Embodiment 11)

Figure 30 is the schematic circuit diagram showing the eleventh embodiment of the present invention. As shown in Figure 30, the basic configuration of the present embodiment is shared with Conventional Example 5 shown in Figure 45. Therefore, designating the reference coding identical [to that of said example] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment.

[0105] The present embodiment differs [from Conventional Example 5] in the following points: [The present embodiment] transposes the connecting location of the inductance L2 and the capacitor C5 (which is parallel-connected to the main switching element Q1 at the high-voltage side) from that in the configuration of Conventional Example 5; as well as a charge circuit 9 that consists of a series circuit of a resistor R14 and the switching element Q8 is provided between the anode of a diode D0 and the connection point of an inductance L2 and the capacitor C5

[0106] Next, the circuit operation of the present embodiment is described in the following with reference to Figure 31. First, until a certain period of time elapses from the time at which the power is turned on, the switching element Q8 is turned

on by operating the starting circuit 8, and the main switching elements Q1 and Q2 are turned off by controlling the oscillation circuit 7; so as to stop the operation of the inverter circuit INV10. During such a halt period of the inverter circuit INV10, the electric current flows via the route of the rectifier DB→ capacitor C5 → resistor R14 → switching element Q8 → rectifier DB; and the capacitor C5 is charged [therewith]. And once the above-mentioned certain period of time has lapsed, the starting circuit 2 turns off the switching element Q8, and controls the oscillation circuit 7 so as to alternately switch the main switching elements Q1 and Q2 between ON and OFF at high frequency. Thereafter, by repeating the ON/OFF switching of the main switching elements Q1 and Q2 with the oscillation circuit 7, high-frequency power, which is determined by the impedances of the load Z as well as the inductance L3 and the capacitor C16, and the drive frequency of the main switching elements Q1 and Q2 (oscillating frequency of the oscillation circuit 7), is supplied to the load Z.

[0107] Additionally, [in] the valley-infill power supply circuit comprising the inductance L2, the capacitor C5 and the diodes D0 and D7, the capacitor C5 is charged when the main switching element Q2 is ON with the electric current that flows via the route of the alternating-current voltage source AC→ rectifier DB→ capacitor C5 → inductance L2 → diode D7 → main switching element Q2 → rectifier DB → alternating-current voltage source AC. Herein, the voltage impressed to the said valley-infill power supply circuit becomes equal to the voltage waveform, for which the input voltage Vi from the rectifier DB is valley-infilled (partially-smoothed) with the end-to-end voltage Vc5 of the capacitor C5 as shown in Figure 31 (a). Furthermore, given that the end-to-end voltage Vc5 of the capacitor C5 will be a predetermined constant value, the voltage of the connection point of the inductance L2 and the capacitor C5 (Vi-Vc5) will form a waveform as shown in Figure 31 (b); and the maximum value will be Vimax-Vc5 (Vimax is the maximum value of the input voltage Vi).

[0108] Meanwhile, for a certain period from the time at which the power was turned on throughout the time during which the inverter circuit INV10 is halted, the switching element Q8 is turned on by the starting circuit 2, so as to conduct the electric current via the route of the rectifier DB→ capacitor C5 → resistor R14 → switching element Q8 → rectifier DB, and charge the capacitor C5 therewith until [the voltage thereof] reaches a predetermined end-to-end voltage. According to the circuit configuration of Conventional Example 5, because the charge circuit 9 is parallel-connected to the main switching element Q2, the maximum value Vimax of the said input voltage Vi is impressed on the switching element Q8 during the operation of the inverter circuit INV10.

[0109] However, according to the present embodiment, because the charge circuit 9 is connected between the anode of the diode D0 and the connection point of the capacitor C5 and the inductance L2, the impressed voltage on the main switching element Q2 is borne by the diode D7. As a result, the voltage will no longer be impressed on the charge circuit 9, allowing the use of an element with a low withstanding voltage for the switching element Q8 of the charge circuit 9. Moreover, the circuit comprising the capacitor C5, the inductance L2, the diodes D0, D7, and the main switching element Q2, because even the voltage, which is impressed on the charge circuit 9 during a step-down chopper operation, drops to Vimax-Vc5 as shown in Figure 31 (b) (the maximum value Vimax of the input current was impressed [thereto] in case of Conventional Example 5), there are benefits such as: An element with a lower withstanding voltage can be used [therein], miniaturization of the components and reduction of cost can be achieved, etc. It is to be noted that other configurations and circuit operations are the same as those of Conventional Example 5. [Accordingly, the present embodiment is capable of preventing stress from being impressed on the main switching elements Q1 and Q2 immediately after the oscillation of the inverter circuit INV10 starts; and further, it eliminates unnecessary power consumption by the resistor R14 because, during the operation of the inverter circuit INV10, the switching element Q8 of the charge circuit 9 is off, inhibiting the charging current from flowing [through the circuit].

[0110] (Embodiment 12)

Figure 32 is the schematic circuit diagram showing the twelfth embodiment of the present invention. As shown in Figure 32, the basic configuration of the present embodiment is shared with Embodiment 11. Therefore, designating the reference coding identical [to that of said embodiment] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment.

[0111] The present embodiment is characterized by being provided with a charge circuit 10, series-connecting a zener diode ZD3 to a resistor R14 instead of a switching element Q8. Herein, the zener voltage of the zener diode ZD3 is set at higher than the maximum value Vimax-Vc5 of the voltage impressed on the connection point of an inductance L2 and a capacitor C5 during the operation of the inverter circuit INV10. (Vimax is the maximum value of the input voltage Vi). Therefore, the zener diode ZD3 is not in a conduction state during the operation of the inverter circuit INV10, and [thus] the electric current does not flow into the charge circuit 10 in the same way as in Embodiment 11.

[0112] Meanwhile, for a certain period from the time at which the power is turned on throughout the time during which the inverter circuit INV10 is halted, because the capacitor C5 is not being charged, the voltage of the connection point of the inductance L2 and the capacitor C5 is about equal to the input voltage Vi from the rectifier DB. Accordingly, the zener diode ZD3 enters a conduction state so as to allow the electric charging of the capacitor C5 to be carried out; and enabling [the present embodiment] to demonstrate the same effect as Embodiment 11. Moreover, because it is not necessary to control the charge circuit 10 by the starting circuit 8 according to the present embodiment, there is also an advantage that it allows simplification of the configuration of the starting circuit 8.

[0113] (Embodiment 13)

Figure 33 is the schematic circuit diagram showing the thirteenth embodiment of the present invention. As shown in Figure 33, the basic configuration of the present embodiment is shared with Embodiment 12. Therefore, designating the reference coding identical [to that of said embodiment] for the shared parts, the explanation thereof shall be omitted herein. Accordingly the following includes the explanations only for the characteristic [features] of the present embodiment.

[0114] The present embodiment differs from Embodiment 12 in connecting the series circuit of the inductance L2 and the capacitor C5 in parallel to the main switching element Q2 at the low-voltage side while connecting the diode D0 in parallel to the main switching element Q1 at the high-voltage side; and further, providing the charge circuit 10 between the cathode of the diode D0 (high-voltage side of the pulsating-current output end of the rectifier DB) and the connection point of the inductance L2 and the capacitor C5.

[0115] Moreover, the circuit operation [of the present invention] differs from [that of Embodiment 12] in the following: The charging current of the capacitor C5 flows via the route of the rectifier DB → main switching element Q1 → diode D7 → inductance L2 → capacitor C5 → rectifier DB when the main switching element Q1 is ON during the operation of the inverter circuit INV10; and the electric discharge of the capacitor C5 is carried out via the diode D0. Otherwise, the rest of the operation is shared with Embodiment 12. Accordingly, the present embodiment can also demonstrate the same effect as Embodiment 12, having set up said zener voltage in such a way that the zener diode ZD3 enters a conduction state when the input voltage Vi from the rectifier DB is higher than the zener voltage of the zener diode ZD3 prior to the start of the oscillation of the inverter circuit INV10.

[0116] (Embodiment 14)

Figure 34 is the schematic circuit diagram showing the fourteenth embodiment of the present invention. As shown in Figure 34, the basic configuration of the present embodiment is shared with Embodiment 13. Therefore, designating the reference coding identical [to that of said embodiment] for the shared parts, the explanation thereof shall be omitted herein. The inverter circuit INV11 according to the present embodiment has a series circuit of the main switching elements Q1' and Q2' consisting of a bipolar transistor connecting the diodes Da and Db in anti-parallel; and is a current-drive type, while the main switching elements Q1 and Q2 in the inverter circuit INV10 according to the embodiments 11 through 13 are voltage-drive types, [each] consisting of a FET. A secondary winding n2 and a tertiary winding n3 of an electric current transformer CT1 are connected to the bases of the main switching elements Q1' and Q2' via the resistors R17 and R18, respectively. Moreover, the primary winding n1 of the electric current transformer CT1 is interposed between the capacitor C16 and the connection point of the main switching elements Q1' and Q2'.

[0117] Also, the starting circuit 12 comprises a series circuit of a capacitor C18 and a resistor R19 connected in parallel to the capacitor C5, a DIAC Q10 interposed between the base of the main switching element Q2' and the connection point of the resistor R19 and the capacitor C18, and a diode D8 interposed between the collector of the main switching element Q2' and the connection point of the resistor R19 and the capacitor C18.

[0118] In the meantime, the charge circuit 11 shares [the configuration] with the configuration of Embodiment 13, both having a series circuit of a resistor R14 and a zener diode ZD3. Furthermore, [according to said charge circuit 11,] the anode of the zener diode ZD3 is connected to the base of a switching element Q9, which consists of a bipolar transistor, while the collector of the switching element Q9 is connected to the high-voltage side of the pulsating-current output end of the rectifier DB via a resistor R15; and the emitter of the switching element Q9 is connected to the connection point of the capacitor C5 and the starting circuit 12.

[0119] Next, the circuit operation of the present embodiment is described as follows:

First is an explanation of the operation of the inverter circuit INV11. When the capacitor C5 is charged, the capacitor C18 of the starting circuit 12 is also charged via the resistor R19. When the end-to-end voltage of the capacitor C18 exceeds a predetermined value, the DIAC Q10 is triggered and turns on. Thereby, a trigger signal is input into the base of the main switching element Q2' of the inverter circuit INV11 and the main switching element Q2' turns on, thereby activating the inverter circuit INV11 (starting the oscillation). When the inverter

circuit INV11 is activated, a high frequency current (resonance current) flows also into the primary winding n1 of the electric current transformer CT1; and a reversed-polarity electromotive force is induced in the secondary winding n2 and the tertiary winding n3, respectively. Thereby, the two [<sic> a pair of] main switching elements Q1' and Q2' are alternately switched between ON and OFF at high frequency. The oscillation then continues by a so-called self-excitation operation. It is to be noted that, with the inverter circuit INV11 being activated, the charging current of the capacitor C18 of the starting circuit 12 flows from the diode D8 to the main switching element Q2' and thus does not charge the capacitor C18. As a result, the DIAC Q10 is not triggered again.

[0120] Now, the operation of the charge circuit 11 is described in the following.

The present embodiment, in the same way as in Embodiment 12 or 13, sets the zener voltage in such a way that the zener diode ZD3 enters a conduction state when the input voltage Vi from the rectifier DB is higher than the zener voltage of the zener diode ZD3. Accordingly, immediately after the power of the alternating-current voltage source AC is turned on, the zener diode ZD3 enters a conduction state switching the switching element Q9 to the ON [state]. [This in turn] causes the electric current to flow via the route of the rectifier DB→ resistor R15 → switching element Q9 → capacitor C5; and thereby the capacitor C5 is charged [with the current]. It is to be noted that because the zener diode ZD3 does not enter a conduction state during the operation of the inverter circuit INV11, the switching element Q9 also turns off, allowing the avoidance of unnecessary power consumption at the resistor R15. Furthermore, when the capacitor C5 is not charged, the capacitor C18 of the starting circuit 12 is not charged, either. Accordingly, if the end-to-end voltage Vc5 of the capacitor C5 is not charged to the predetermined level in the event that an undervoltage condition (or power failure) instantaneously takes place in the alternating-current voltage source AC immediately after the power is turned on, in this case, the inverter circuit INV11 does not operate, thus making it possible to suppress the stress impressed on the main switching elements Q1' and Q2' generated due to fluctuations of the power-supply voltage VAC of the alternating-current voltage source AC.

[0121] The above-mentioned embodiments 11 through 14 describe [the present invention] using a so-called dual-switching type, which uses two main switching elements, as the inverter circuit. However, without limiting thereto in particular any types of inverter circuit, for example, single-switch type or four four-switch types, may be used [as the inverter circuit], as long as it has a circuit configuration in which the capacitor C5 in the power supply circuit is charged via the ON-OFF operation of the main switching elements and operates as a partial-smoothing

(valley-infill) power source.

[0122]

[Effects of the Invention]

The invention of Claim 1 provides an electric-power supply unit comprising a rectifier for rectifying the alternating-current voltage source; a first capacitor connected between the output ends of the rectifier, an inverter circuit provided with a first and a second main switching elements that are series-connected to both ends of the first capacitor, as well as a resonant circuit that is parallel-connected to either one of the main switching elements, and a control circuit for alternately switching the first and the second main switching elements between ON and OFF [states] at high frequency. Said resonant circuit is configured having a first inductance for resonance, a second capacitor for resonance parallel-connected to a load, a third capacitor for coupling direct current, and a fourth capacitor parallel-connected with the first diode; while consisting of said parallel circuit of the fourth capacitor and the first diode being connected between the series circuits of the first capacitor and the first and the second main switching elements; a sixth capacitor and a series circuit of the fifth capacitor and the second inductance as well as the second diode parallel-connected to the series circuit of the first and the second main switching elements; and the connection point of the first and the second main switching elements and the connection point of the second inductance and the second diode connected to the third diode. [Said electric-power supply unit] is [further] provided with a switching element in parallel to the second diode, and switches said switching element between ON and OFF by said control circuit according to the load state. Therefore, by turning off said switching element during normal [conditions], the power-supply voltage of the inverter circuit is valley-infilled (partially-smoothed), so to speak, enabling the improvement of the load current waveform. And by turning on said switching element during a light-load [state], [it] can also provide an effect of preventing an increase in the power-supply voltage of the inverter circuit.

[0123] The invention of Claim 2 is provided with a rectifier for rectifying the alternating-current voltage source; a first capacitor connected to the rectifier; an inverter circuit provided with a first and a second main switching elements series-connected in parallel to the first capacitor, as well as a resonant circuit parallel-connected to either one of the main switching elements; and a control circuit for alternately switching the first and the second main switching elements between ON and OFF [states] at high frequency. Said resonant circuit is configured having a first inductance for resonance, a second capacitor for

resonance parallel-connected to a load, a third capacitor for coupling direct current, and a fourth capacitor to which the first diode is parallel-connected, while also consisting of said parallel circuit of the fourth capacitor and the first diode connected between the first capacitor and the series circuits of the first and the second main switching elements; a sixth capacitor and a series circuit of the fifth capacitor and the second inductance as well as the second diode parallel-connected to the series circuit of the first and the second main switching elements; and the connection point of the first and the second main switching elements and the connection point of the second inductance and the second diode connected to the third diode. [Said electric-power supply unit] is [further] provided with a pair of switching terminals provided at both ends of the second inductance, a common terminal provided at the high-voltage side of the first main switching element, and a switching circuit that, controlled by said control circuit, alternatively switches and connects said common terminal to said pair of switching terminals. Therefore, by switching said common terminal of the switching circuit to one of the switching terminals during normal [conditions],

the power-supply voltage of the inverter circuit is valley-infilled (partially-smoothed), so to speak, enabling an improvement of the load current waveform. And by switching said common terminal of the switching circuit to another switching terminal during a light-load [state], [it] can also provide an effect of preventing an increase in the power-supply voltage of the inverter circuit.

[0124] The invention of Claim 3 is provided with a switching element that is switched between ON and OFF by said control circuit, and short-circuits between both ends of said fourth capacitor. Accordingly, by short-circuiting the fourth capacitor switching said switching element to the ON [state], [it] can provide an effect of preventing an increase in the power-supply voltage of the inverter circuit, even when the load is at the minimum [<sic> lightest], such as during a no-load [state], or in case of other abnormal conditions, etc.

[0125] The invention of Claim 4 consists of a series circuit of the switching element that is switched between ON and OFF by said control circuit and a 7th capacitor parallel-connected to the fourth capacitor. [Accordingly,] the 7th capacitor is selectively connected to the fourth capacitor through the ON-OFF [operation] of said switching element, [through which] the apparent capacity of the fourth capacitor is altered. Thereby, it can provide an effect of preventing an increase in the power-supply voltage of the inverter circuit and a reduction of the stress on the main switching elements even when the power supply to the load is limited [<sic> narrowed down].

[0126] The invention of Claim 5 is provided with a switching element for

short-circuiting, which is switched between ON and OFF by said control circuit and short-circuits between both ends of said fourth capacitor, and comprises the series circuit of said switching element for switching (said switch between ON and OFF carried out by said control circuit) and the 7th capacitor being parallel-connected to the fourth capacitor. Accordingly, by short-circuiting the fourth capacitor switching said switching element for short-circuiting to the ON [state], it can facilitate prevention of the power-supply voltage of the inverter circuit even when the load is at the minimum [<sic> lightest], such as during a no-load [state], or in case of other abnormal conditions, etc. In addition, the apparent capacity of the fourth capacitor is altered with the 7th capacitor being selectively connected to the fourth capacitor through the ON-OFF [operation] of the switching element ([which is adapted] for said switching). Thus, it can provide an effect of facilitating prevention of an increase in the power-supply voltage of the inverter circuit even when the power supply to the load is limited [<sic> narrowed down], as well as a reduction of the stress to the main switching elements.

[0127] According to the invention of Claim 6, the electric-power supply unit is provided with a rectifier for rectifying the alternating-current voltage source; an inverter circuit that converts the output of said rectifier into a high frequency output and supplies it to a load, said inverter circuit being provided with one or multiple main switching elements switched at high frequency as well as having a resonant circuit comprised of one or multiple inductances for resonance, a capacitor for resonance, a capacitor (which is adapted for cutting direct-current component) and a load; and a power-supply circuit that is provided with one or multiple capacitors for partial smoothing and that performs partial-smoothing of the output of said rectifier. Said electric-power supply unit is further provided with a feedback means for returning a portion of the high frequency output of said inverter circuit to the output side of the rectifier via said resonant circuit, and a control means for causing the oscillation of said inverter circuit to start when the absolute value of the alternating-current supply voltage is lower than that of the end-to-end voltage of the capacitor (which is adapted for partial smoothing). Accordingly, the oscillation of the inverter circuit is started by the control means when the absolute value of the alternating-current supply voltage is lower than that of the end-to-end voltage of the capacitor (which is adapted for partial smoothing), during the power-on state of the alternating-current voltage source; and therefore [the present invention] can provide an effect of reducing the stress applied to the main switching elements of the inverter circuit during the process of charging the capacitor (which is adapted for cutting direct-current component) during a steady state.

[0128] The invention of Claim 7 is provided with a means for charging the capacitor that is adopted for partial smoothing before the oscillation of said inverter circuit starts. Therefore, by charging the capacitor (which is adopted for partial smoothing) before the oscillation of the inverter circuit starts, it can reduce the electric current flowing into the capacitor (which is adopted for partial smoothing) when the oscillation of the inverter circuit starts. Accordingly, it can provide an effect of reducing the stress impressed on the main switching elements of the inverter circuit.

[0129] The invention of Claim 8 can provide an effect of reducing the stress impressed on the main switching elements of the inverter circuit, having been provided with a means for charging the capacitor (which is adapted for cutting direct-current component) up until the end-to-end voltage of the capacitor (which is adapted for cutting direct-current component and which comprises said resonant circuit) becomes [<sic> is in a state] lower than the end-to-end voltage of the capacitor (which is adopted for partial smoothing), before the oscillation of said inverter circuit starts.

[0130] The invention of Claim 9 can provide an effect of reducing the stress impressed on the main switching elements of the inverter circuit, having been provided with a detection means for detecting the zero-cross of the alternating-current supply voltage, wherein said control means starts the oscillation of said inverter circuit when the detection means detects the zero-cross and thus the end-to-end voltage of the capacitor (which is adapted for cutting the direct-current component) is close to zero at a place near the zero-cross point of the alternating-current supply voltage.

[0131] According to the invention of Claim 10, the electric-power supply unit has a rectifier for rectifying the alternating-current voltage source; an inverter circuit that is provided with one or multiple main switching elements switched at high frequency and that converts the direct-current output into a high-frequency AC output and supplies it to a load; and one or multiple capacitors as well as inductances. Said electric-power supply unit is also provided with a partial smoothing circuit that supplies said direct-current output (which is [obtained by] charging said capacitor through the ON-OFF operation of said main switching elements and partially-smoothing the pulsating current output of the rectifier) to said inverter circuit. Additionally, in said electric-power supply unit, the capacitor of said partial smoothing circuit is series-connected to said main switching elements via the inductance; while a charge circuit, which charges said capacitor before the operation of said inverter circuit starts up, is formed by being parallel-connected to the series circuit of said inductance and the main switching

elements. Accordingly, not only can the invention of Claim 10 reduce the stress applied to main switching elements by the charge circuit at the time when the operation of said inverter circuit starts up, but it can also reduce the voltage impressed on the charge circuit during the operation of the inverter circuit. Moreover, it can also lower the withstanding voltage of the circuit component used for the charge circuit. And accordingly, [the invention of Claim 10] can provide effects [such as] enabling miniaturization and simplification of the charge circuit.

[0132] The invention of Claim 11 can provide an effect of eliminating unnecessary power consumption in the charge circuit, because it is configured in such a way that the electric charging [operation of said capacitor] by said charge circuit is discontinued once said capacitor is charged up to or greater than a prescribed level.

According to the invention of Claim 12, said charge circuit is equipped with an opening-and-closing means that opens and closes the electric charging route of said capacitor; therefore, during the operation of the inverter circuit, by setting the opening-and-closing means in the open [state], the electric charging of said capacitor by the charge circuit will no longer be performed. In this way, the invention of Claim 12 can provide an effect of eliminating unnecessary power consumption for use in [<sic> due to] the charging current.

[0133] According to the invention of Claim 13, said opening-and-closing means starts operation ahead of the main switching elements of the inverter circuit; and the ON-OFF operation thereof is repeated in synchronization with the ON-OFF operation of said main switching elements, making control of the opening-and-closing means easier. In this way, the invention of Claim 13 can provide an effect of facilitating simplification of the circuit.

According to the invention of Claim 14, the ON-OFF operation of said opening-and-closing means is repeated in accordance with the charge voltage level of said capacitor, making control of the opening-and-closing means easier. In this way, the invention of Claim 14 can provide an effect of facilitating simplification of the circuit.

[Brief Description of the Diagrams]

[Figure 1] is a schematic circuit diagram showing Embodiment 1.

[Figure 2] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 3] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 4] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 5] is a signal waveform chart explaining the operation of said [embodiment] above.

[Figure 6] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 7] is a schematic circuit diagram showing Embodiment 2.

[Figure 8] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 9] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 10] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 11] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 12] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 13] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 14] is a schematic circuit diagram showing Embodiment 3.

[Figure 15] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 16] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 17] is a schematic diagram explaining the operation of said [embodiment] above.

[Figure 18] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 19] is a schematic circuit diagram showing Embodiment 4.

[Figure 20] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 21] is a schematic circuit diagram showing Embodiment 5.

[Figure 22] is a schematic circuit diagram showing Embodiment 6.

[Figure 23] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 24] It is the circuit configuration diagram of said [embodiment] above, including a concrete circuit diagram of the principal part.

[Figure 25] is a schematic circuit diagram showing Embodiment 7.

[Figure 26] is a schematic circuit diagram showing Embodiment 8.

[Figure 27] is a waveform chart explaining the operation of said [embodiment]

above.

[Figure 28] is a schematic circuit diagram showing Embodiment 9.

[Figure 29] is a schematic circuit diagram showing Embodiment 10.

[Figure 30] is a schematic circuit diagram showing Embodiment 11.

[Figure 31] is a waveform chart explaining the operation of said [embodiment] above.

[Figure 32] is a schematic circuit diagram showing Embodiment 12.

[Figure 33] is a schematic circuit diagram showing Embodiment 13.

[Figure 34] is a schematic circuit diagram showing Embodiment 14.

Figure 35] is a schematic circuit diagram showing Conventional Example 1.

[Figure 36] is a waveform chart explaining the operation of said [example] above.

Figure 37] is a schematic circuit diagram showing Conventional Example 2.

[Figure 38] is a waveform chart explaining the operation of said [example] above.

Figure 39] is a schematic circuit diagram showing Conventional Example 3.

[Figure 40] is a waveform chart explaining the operation of said [example] above.

[Figure 41] is a schematic diagram explaining the operation of said [example] above.

[Figure 42] is a schematic diagram explaining the operation of said [example] above.

[Figure 43] is a waveform chart explaining the operation of said [example] above.

Figure 44] is a schematic circuit diagram showing Conventional Example 4.

Figure 45] is a schematic circuit diagram showing Conventional Example 5.

[Figure 46] is a waveform chart explaining the operation of said [example] above.

[Figure 47] is a waveform chart explaining the operation of said [example] above.

[Figure 48] is a waveform chart explaining the operation of said [example] above.

Figure 49] is a waveform chart explaining the operation of said [example] above, the figures (b) and (c) showing the (i) and (ro) parts of said figure (a) in expanded form, respectively.

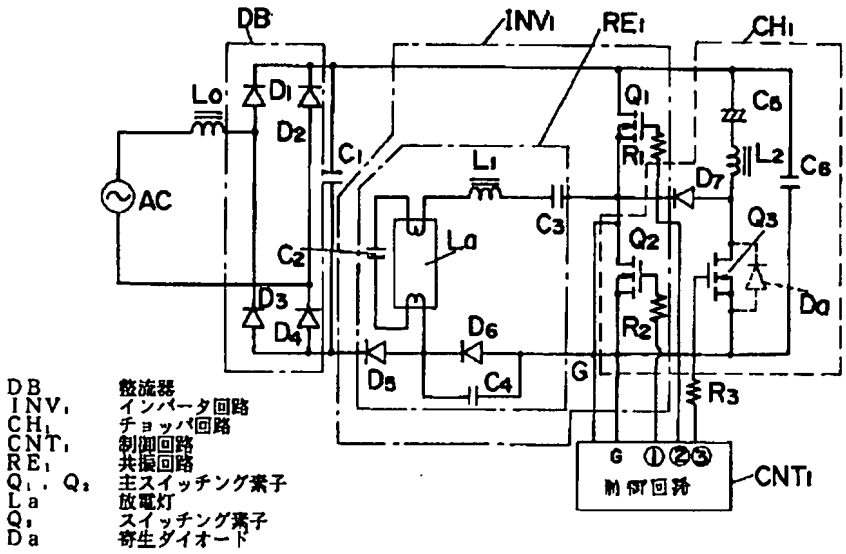
[Figure 50] is a waveform chart explaining the operation of said [example] above.

[Description of Reference Coding]

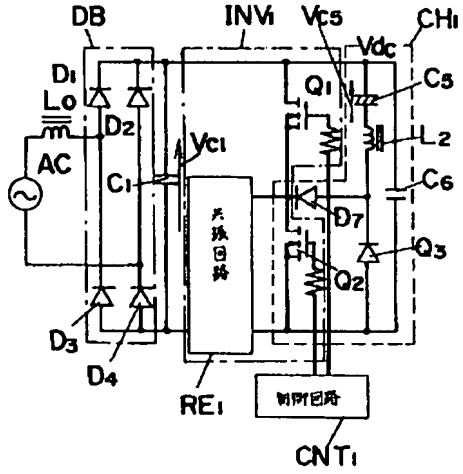
DB	Rectifier
INV1	Inverter circuit
CH1	Chopper circuit
CNT1	Control circuit
RE1	Resonant circuit
Q1, Q2	Main switching element

La	Electric-discharge lamp
Q3	Switching element
Da	Parasitic diode

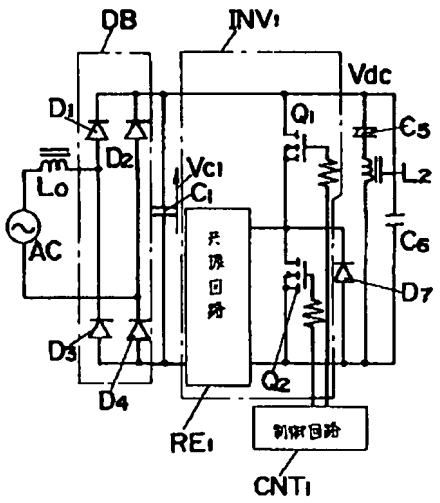
【Figure 1】



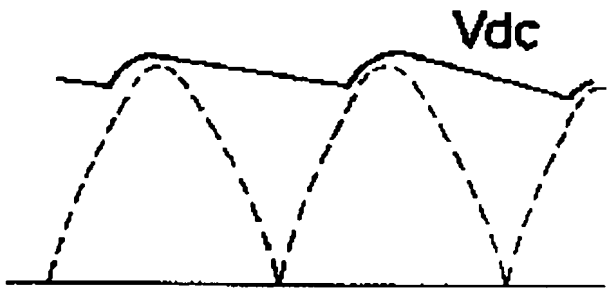
【Figure 2】



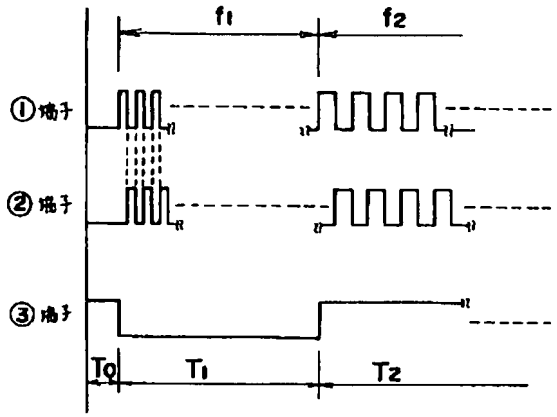
【Figure 3】



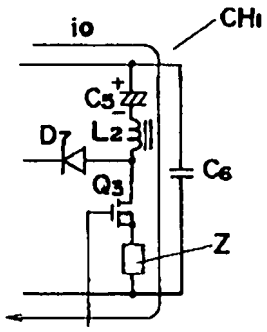
【Figure 4】



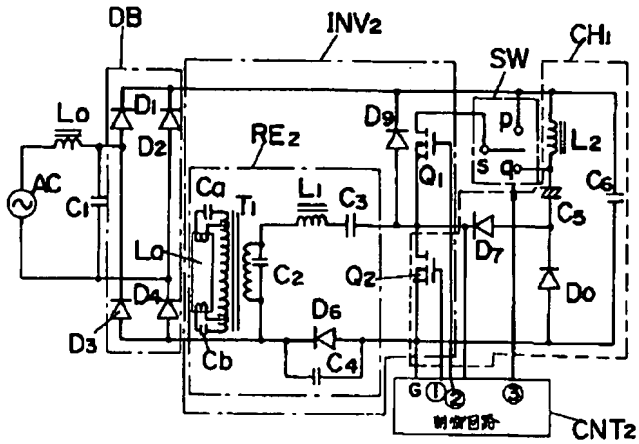
【Figure 5】



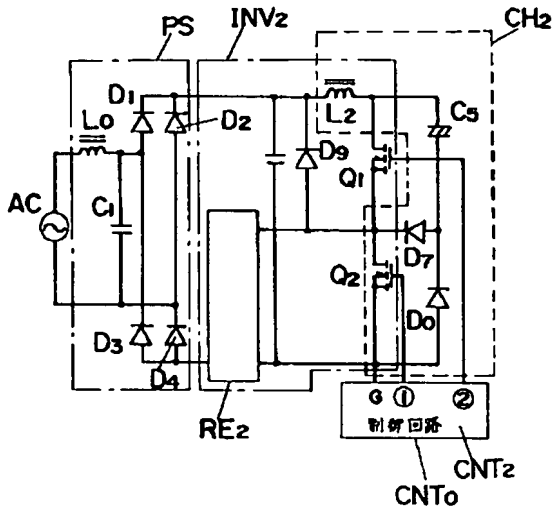
【Figure 6】



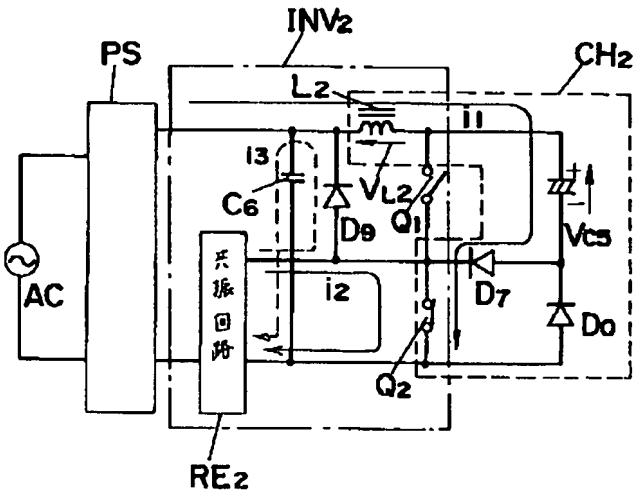
【Figure 7】



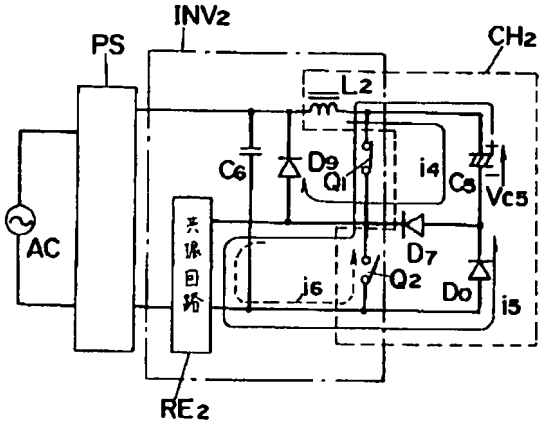
【Figure 8】



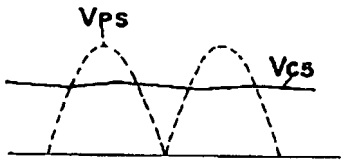
【Figure 9】



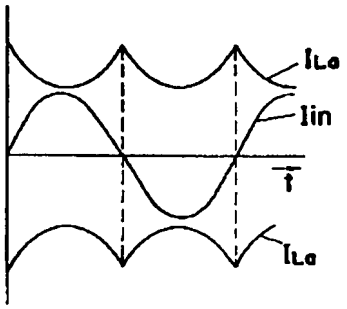
【Figure 10】



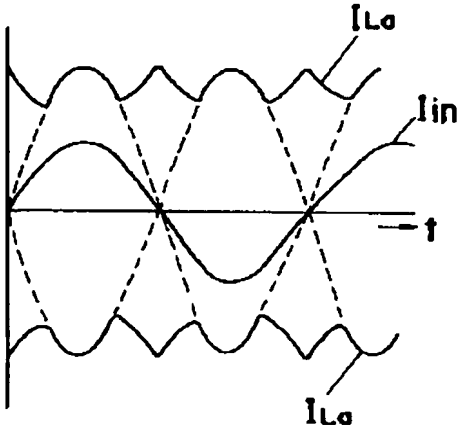
【Figure 11】



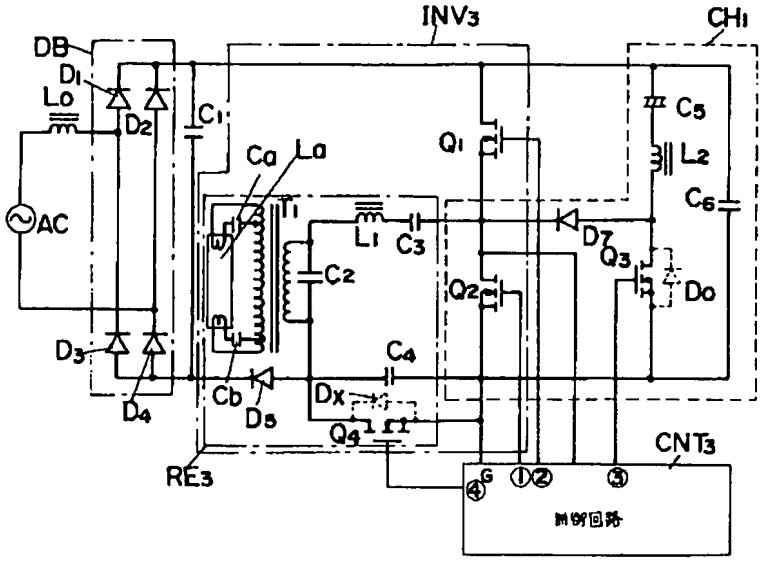
【Figure 1 2】



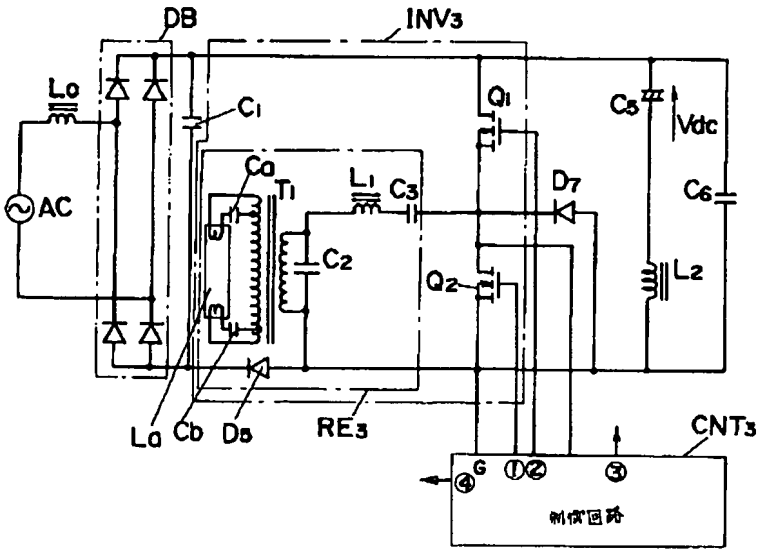
【Figure 1 3】



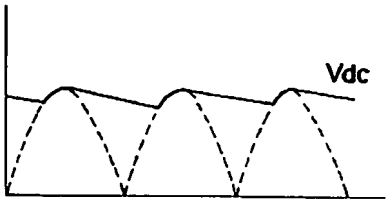
【Figure 1 4】



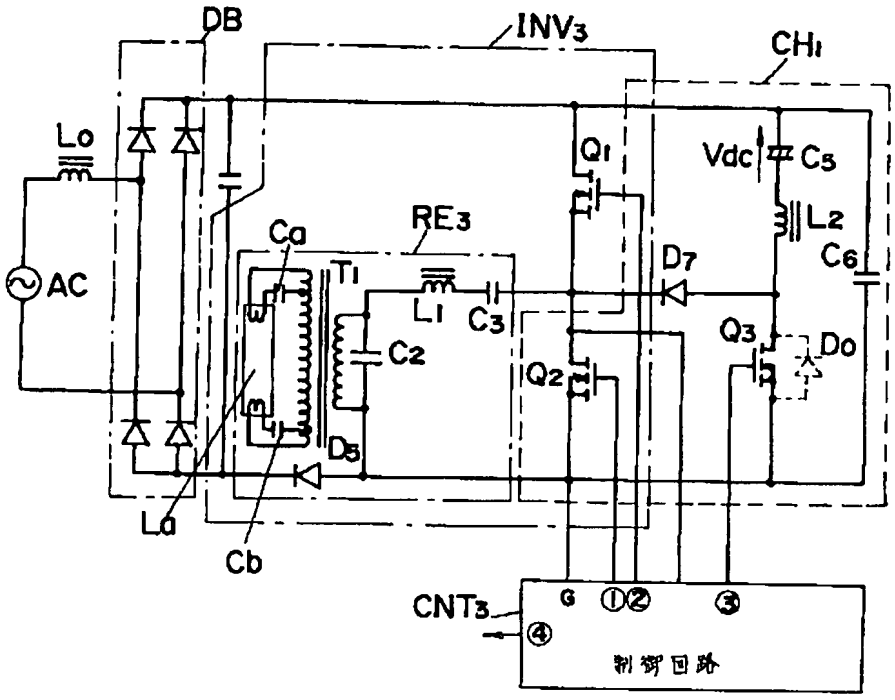
【Figure 15】



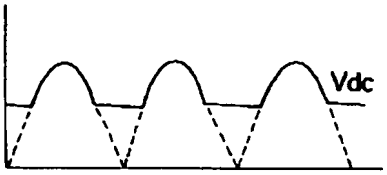
【Figure 16】



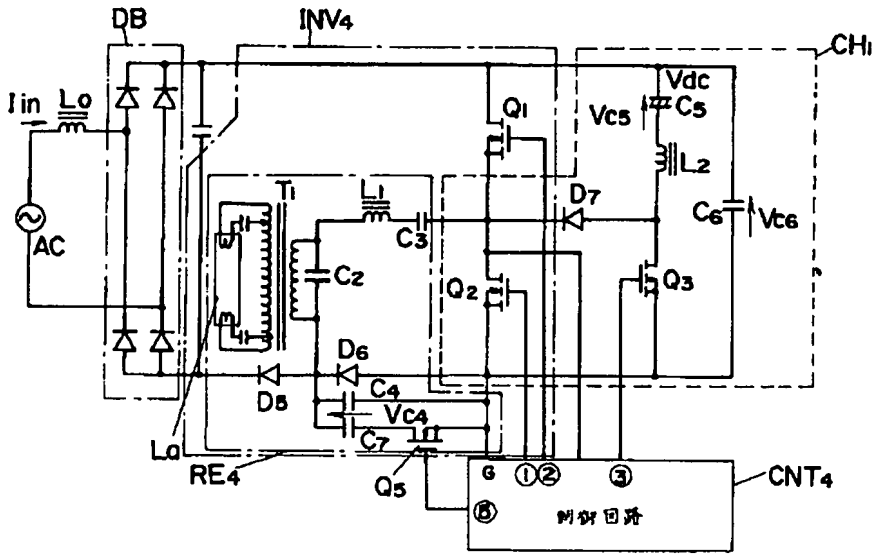
【Figure 17】



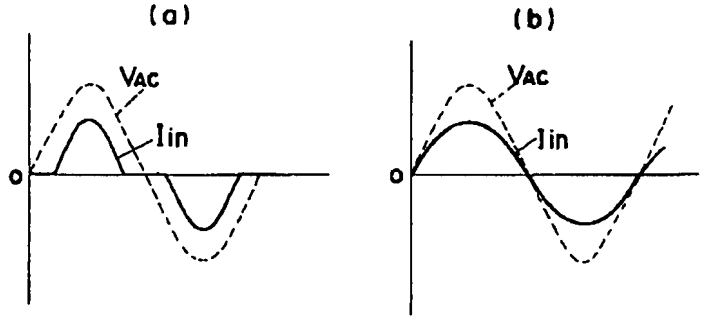
【Figure 18】



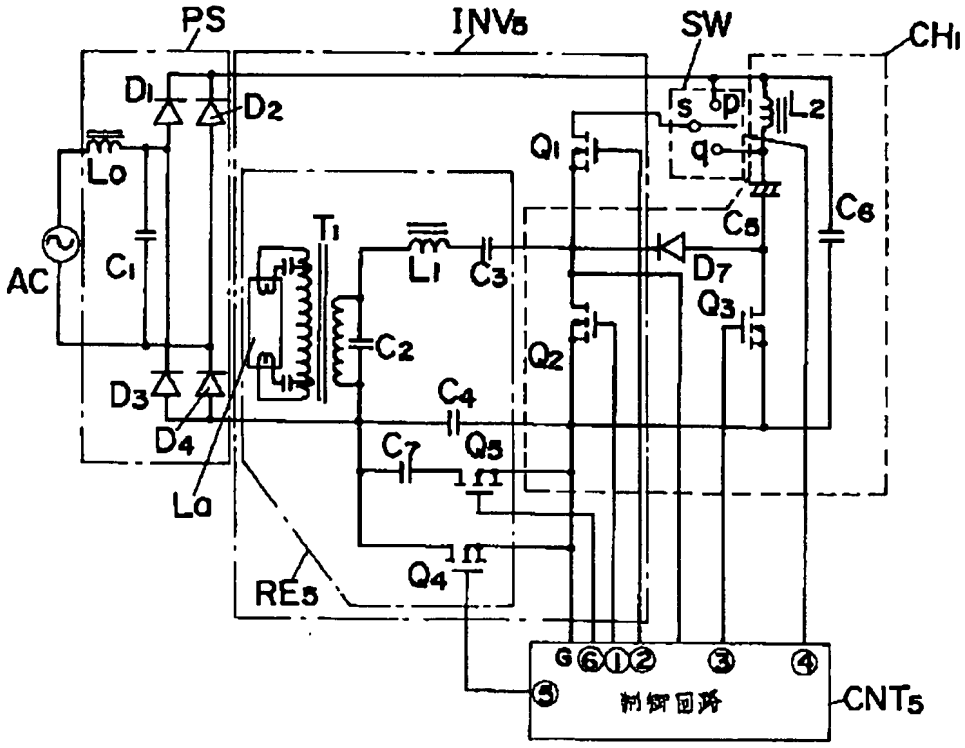
【Figure 19】



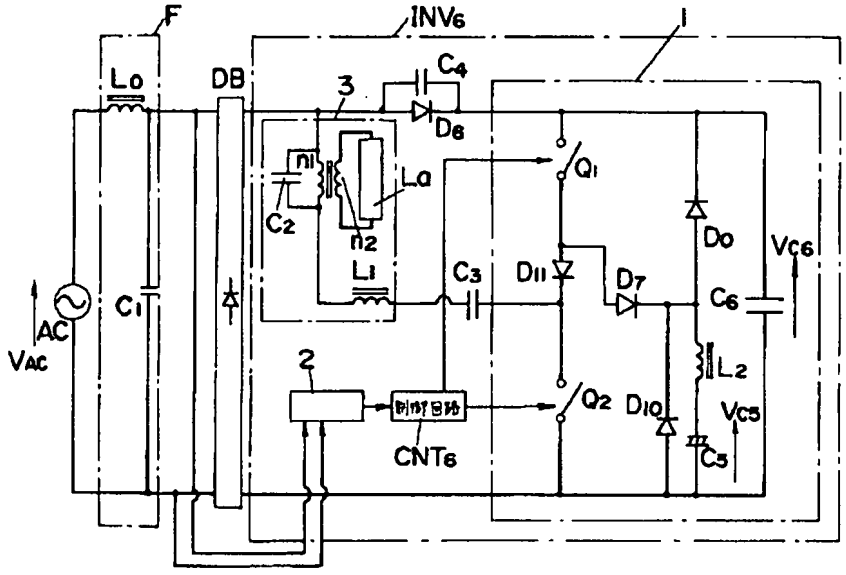
【Figure 20】



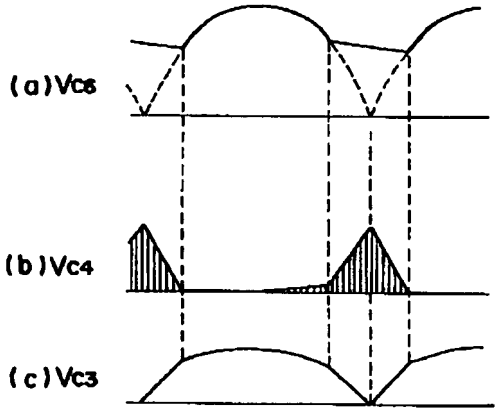
【Figure 2 1】



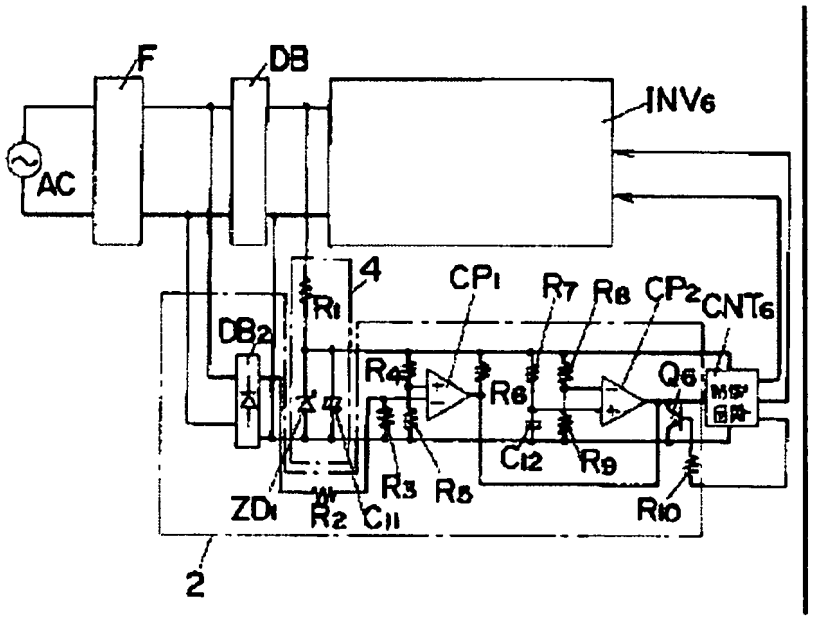
【Figure 2 2】



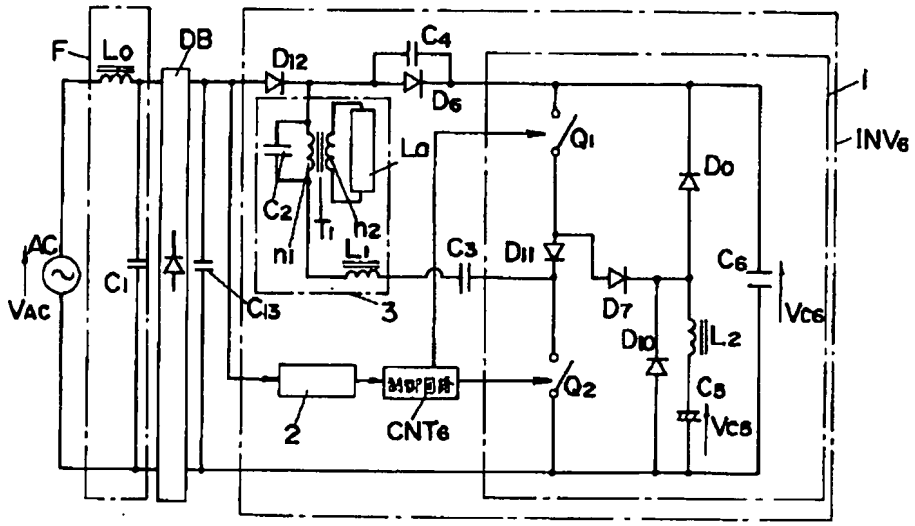
【Figure 2 3】



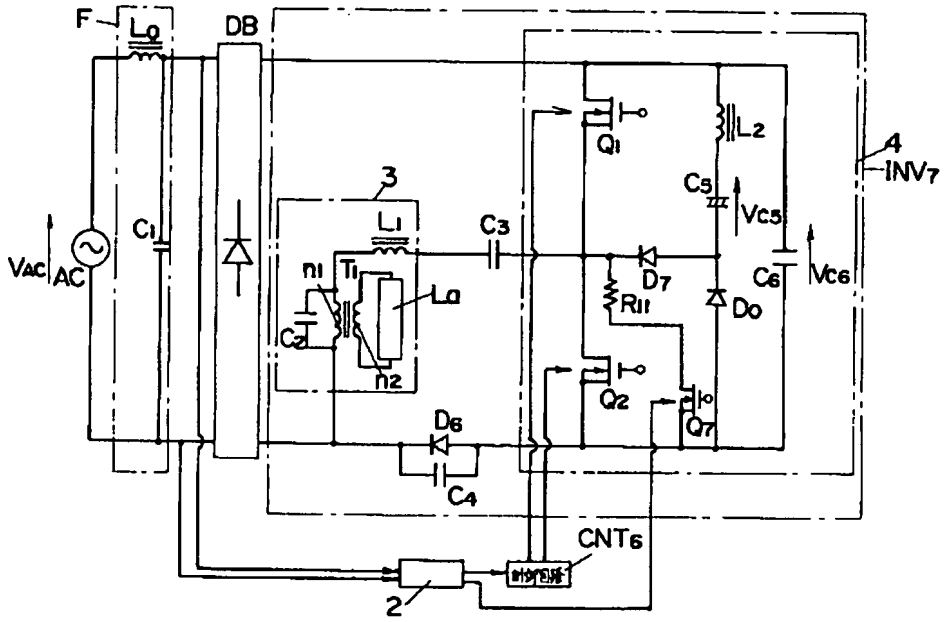
【Figure 2 4】



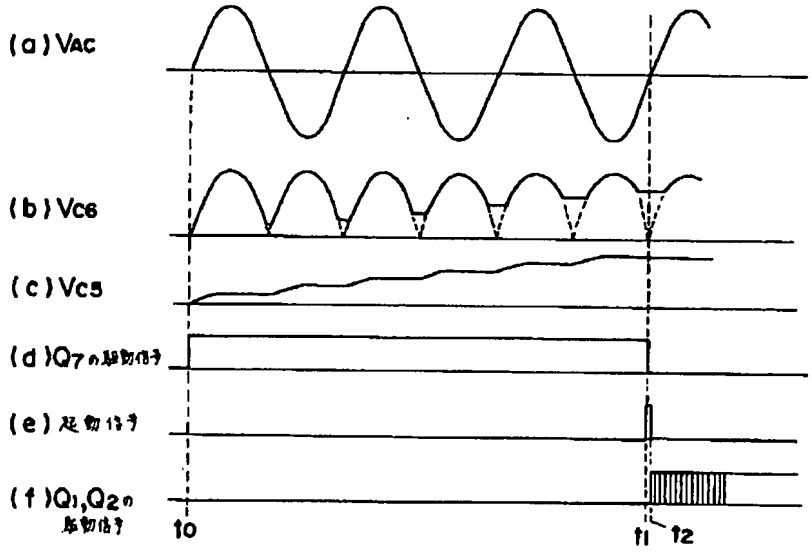
【Figure 2 5】



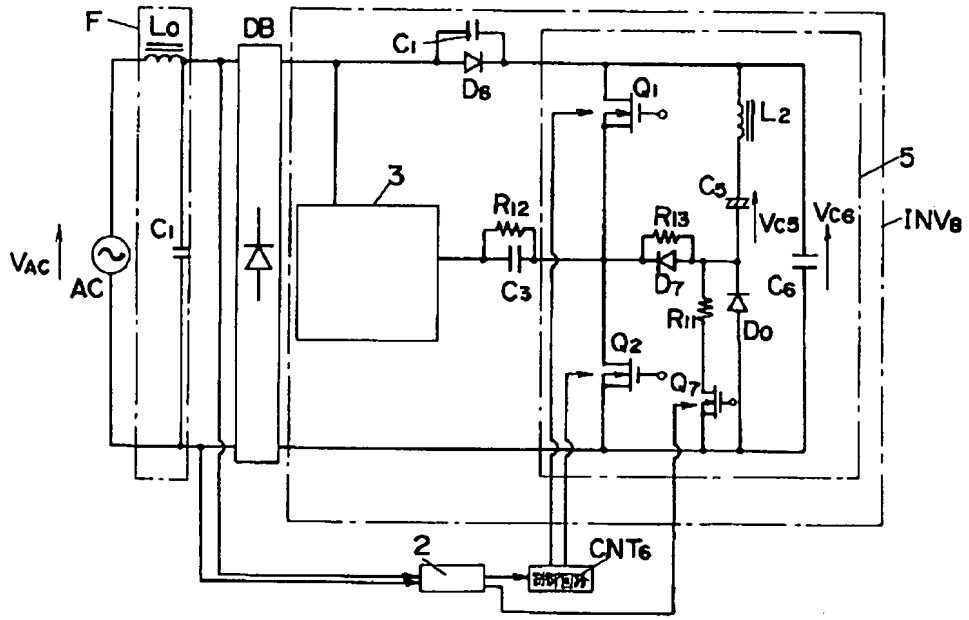
【Figure 2 6】



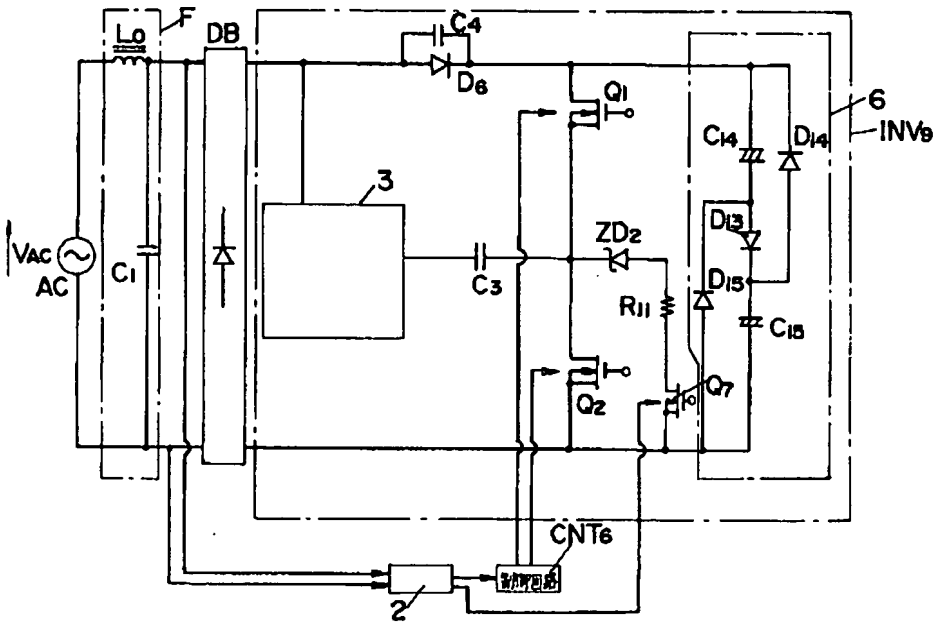
【Figure 2 7】



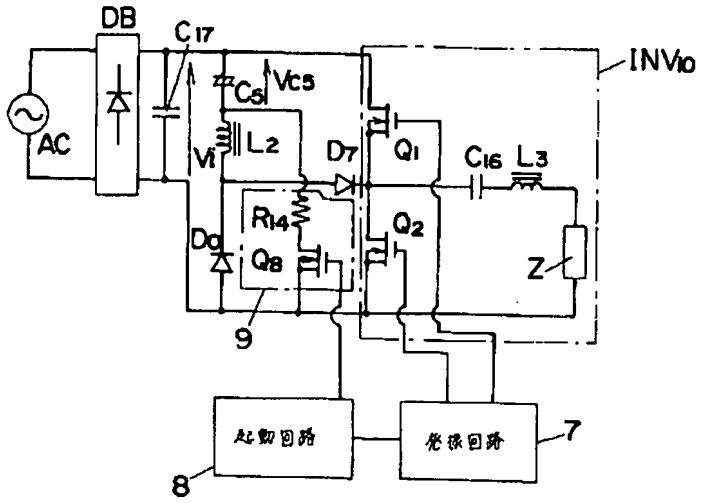
【Figure 2 8】



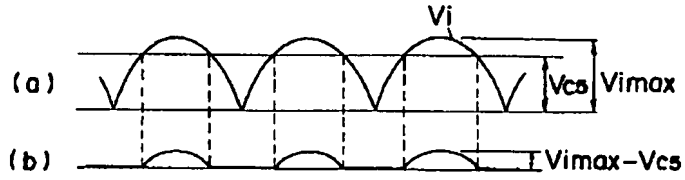
【Figure 2 9】



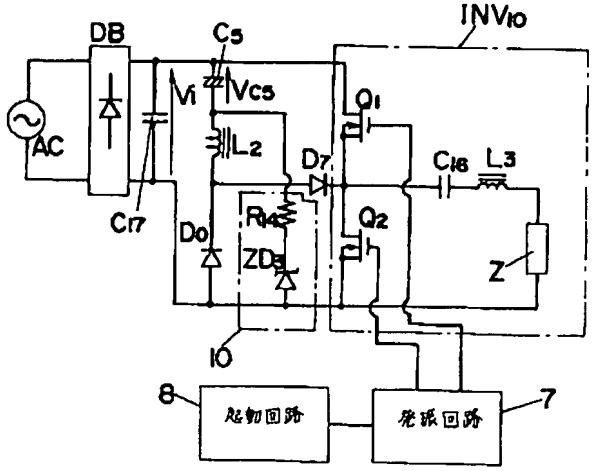
【Figure 3 0】



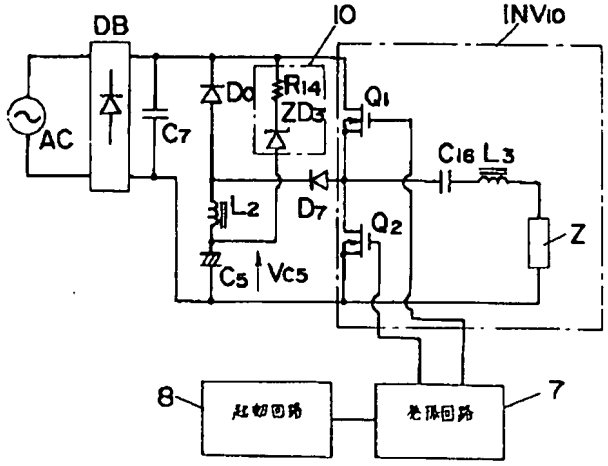
【Figure 3 1】



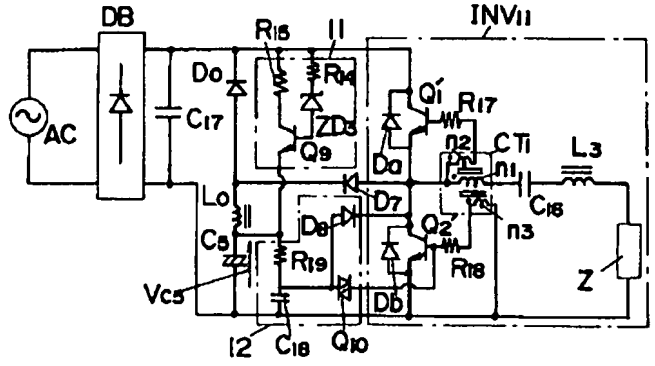
【Figure 3 2】



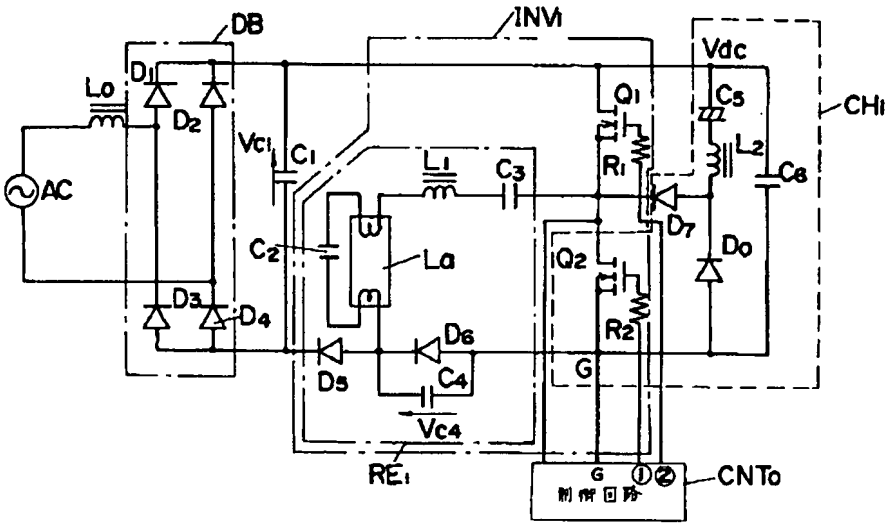
【Figure 3 3】



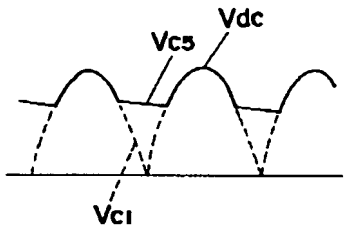
【Figure 3 4】



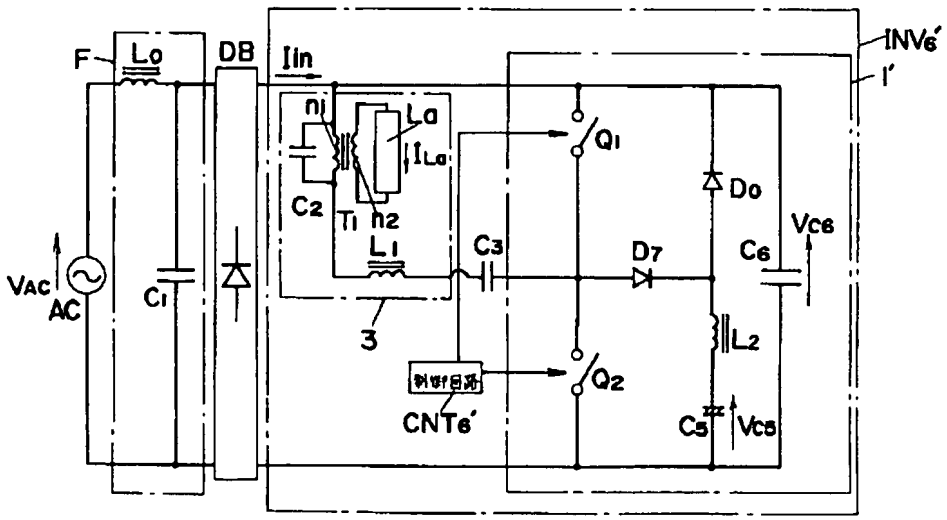
【Figure 3 5】



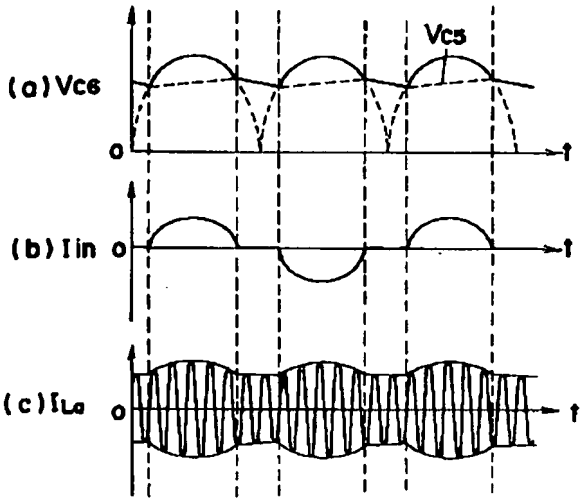
【Figure 3 6】



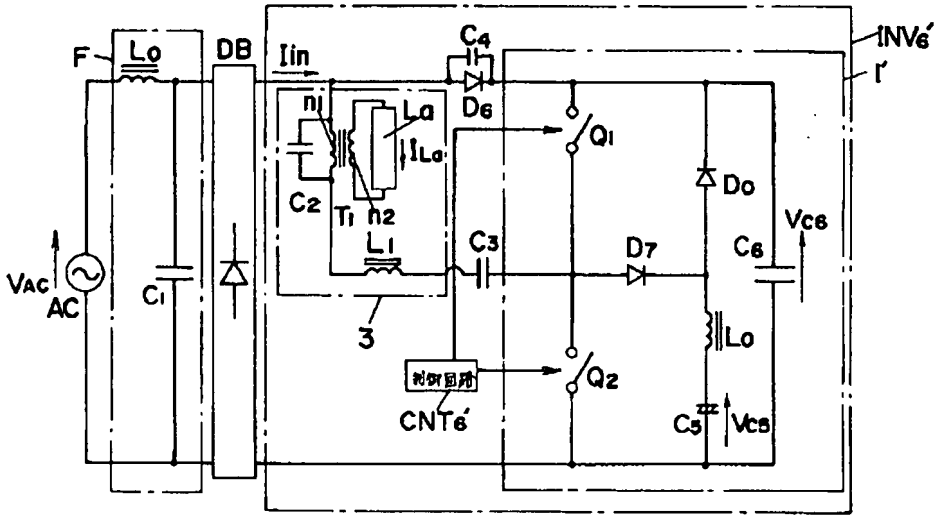
【Figure 3 7】



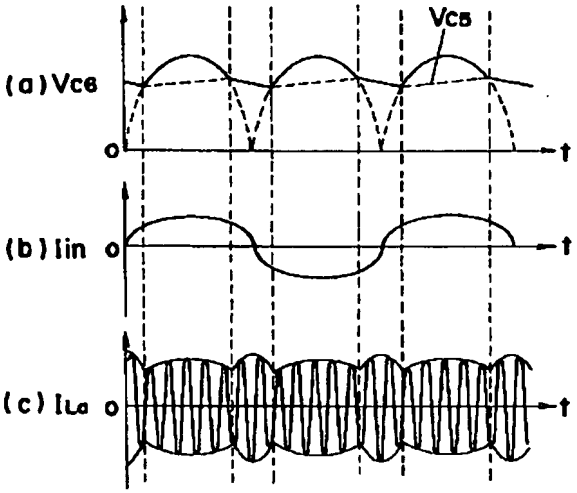
【Figure 3 8】



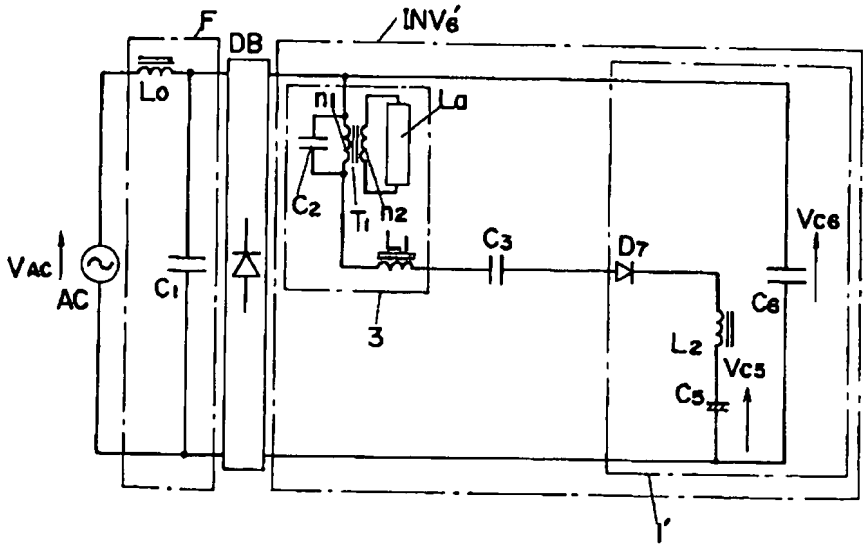
【Figure 3 9】



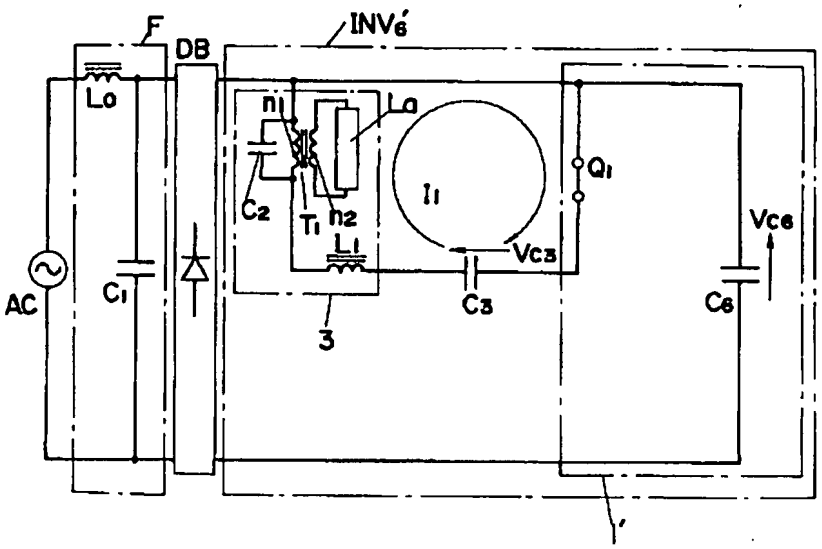
【Figure 4 0】



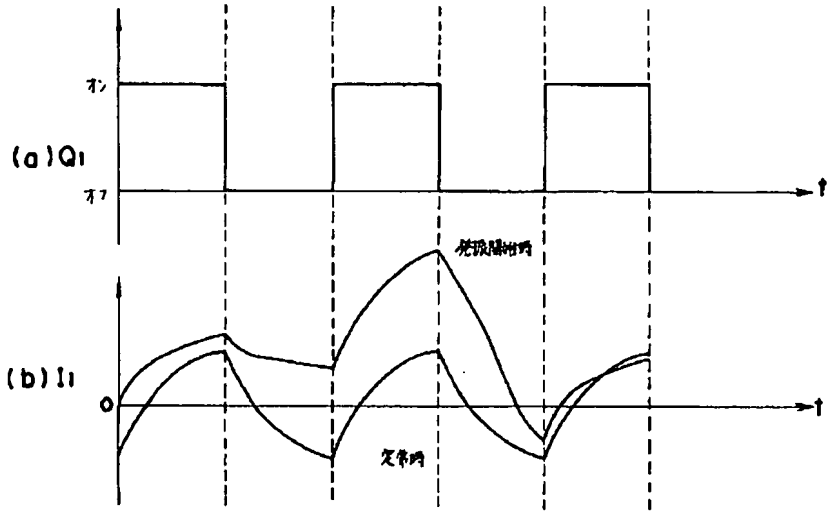
【Figure 4 1】



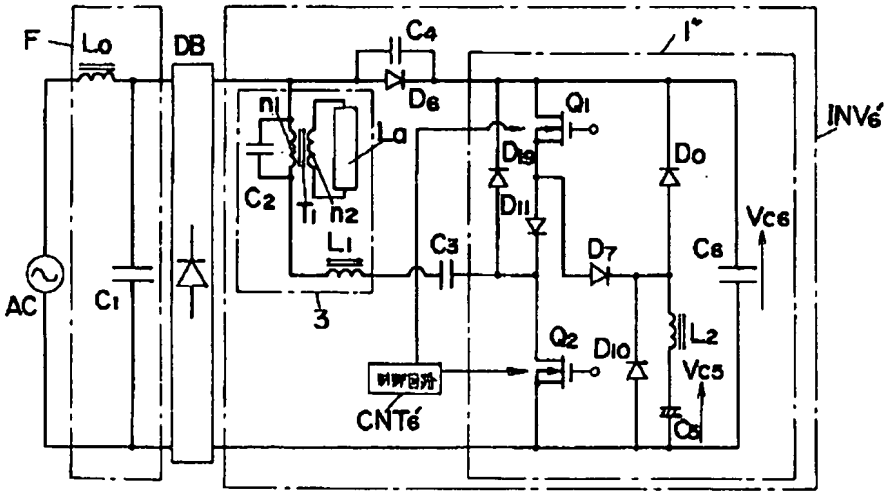
【Figure 4 2】



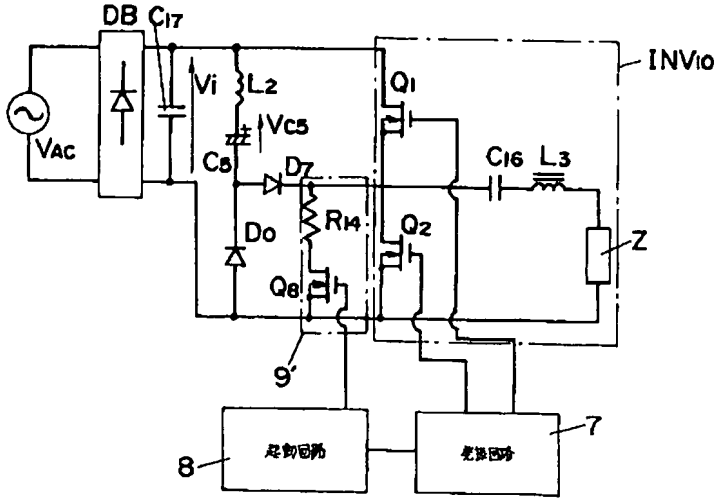
【Figure 4 3】



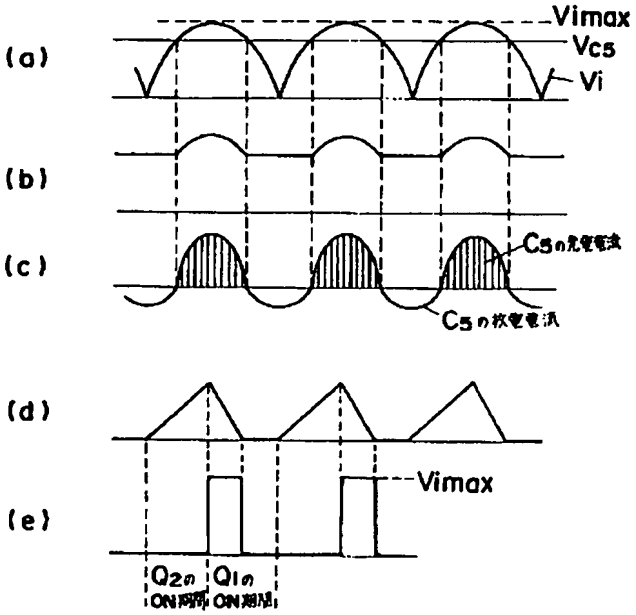
【Figure 4 4】



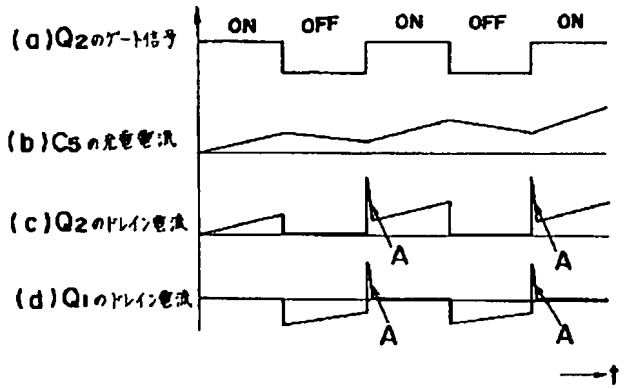
【Figure 4 5】



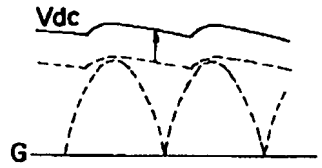
【Figure 4 6】



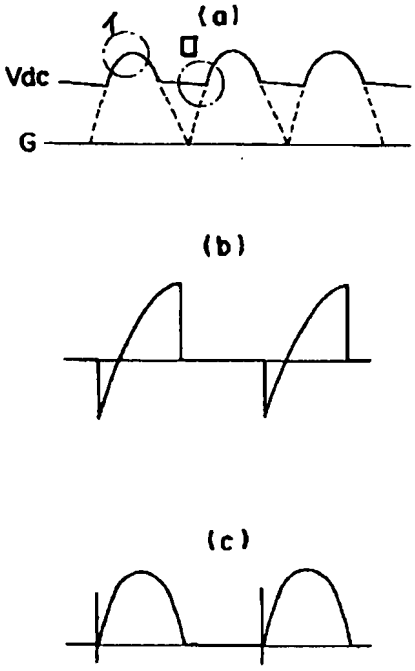
【Figure 4 7】



【Figure 4 8】



【Figure 4 9】



【Figure 5 0】